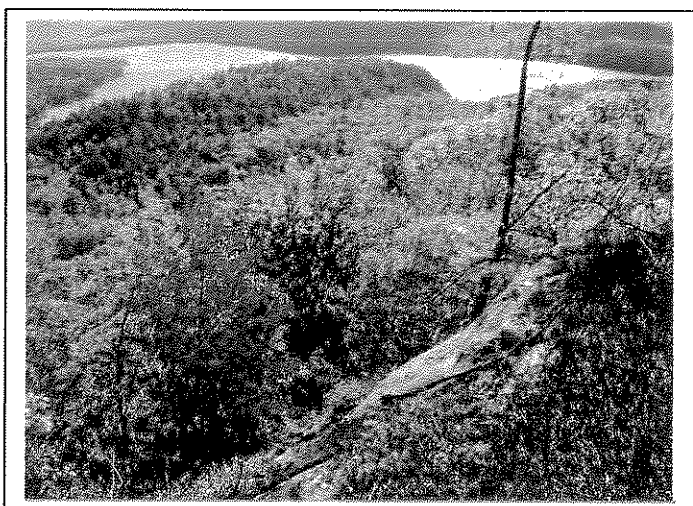
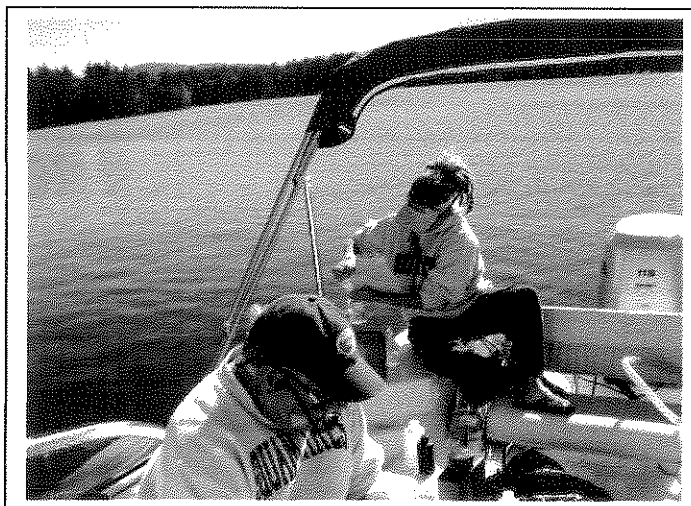
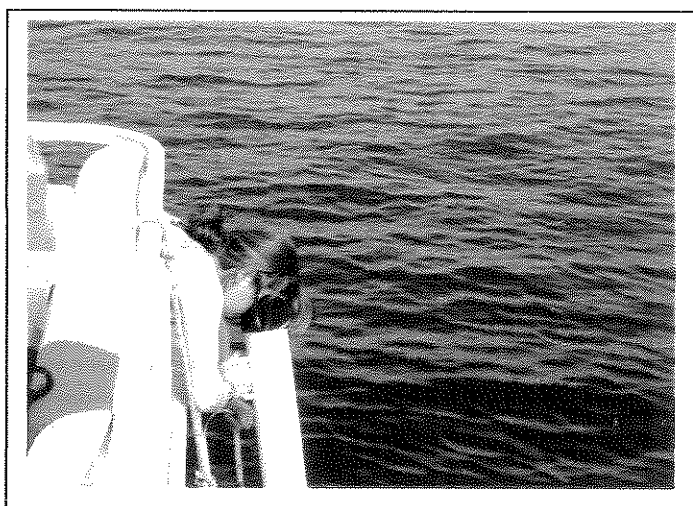
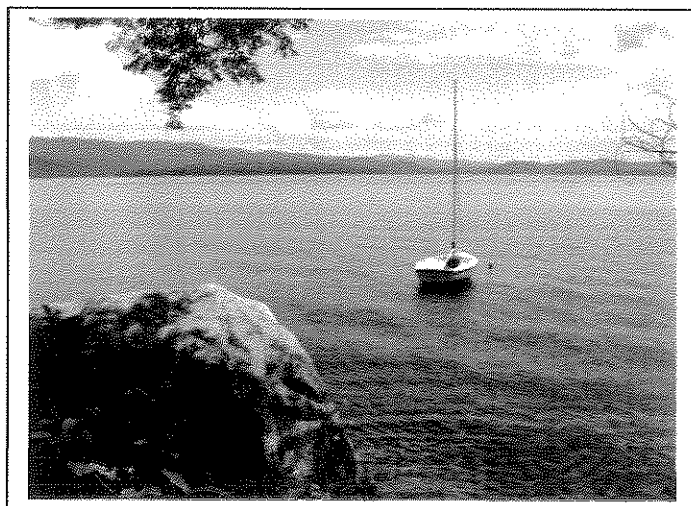


WINNIPESAUKEE (ALTON)

Water Quality Monitoring: 2008

Summary and Recommendations

NH LAKES LAY MONITORING PROGRAM



By: Robert Craycraft & Jeffrey Schloss

Center for Freshwater Biology
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UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

To obtain additional information on the NH Lakes Lay Monitoring Program (NH LLMP) contact the Coordinator (Jeff Schloss) at 603-862-3848 or Assistant Coordinator (Bob Craycraft) at 603-862-3696.

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PREFACE

This report contains the findings of a water quality survey of Lake Winnepesaukee, Alton New Hampshire, conducted in the summer of 2008 by the University of New Hampshire **Center For Freshwater Biology (CFB)** in conjunction with interested residents who reside in the Town of Alton.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of the year 2008 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

The 2008 sampling season marked the thirtieth anniversary for the NH Lakes Lay Monitoring Program (LLMP). The LLMP has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a database for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

The NH LLMP has gained an international reputation as a successful cooperative monitoring, education and research program. Current projects include: the use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), and intensive watershed monitoring for the development of watershed nutrient budgets, investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative cost share funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 2008 sampling season was another exciting year for the

Figure 1. LLMP Objectives

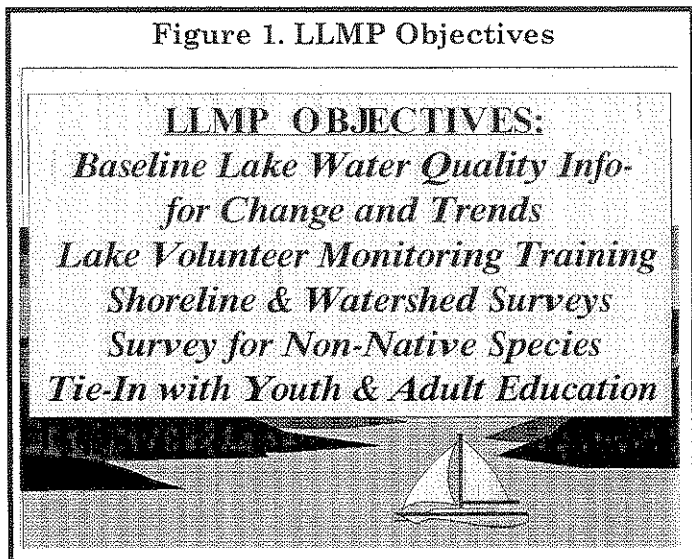


Table 1. Awards & Recognition

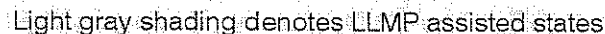
1983- NH Environmental Law Council Award
1984- Governor's Volunteer Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" award funded
1990- NH Journal TV coverage NHPTV
1991- Renew America Award
Environmental Success Index
White House Reception / Briefing
1992- EPA Administrators Award
1993- NH Lakes Association Award
1994- EPA Office of Watersheds Award
1995- Winnepesaukee Watershed Project
1998- Governor's Proclamation for 20 th Anniversary
1999- EPA Watershed Academy Host
2001- Lake Chocorua Project highlighted at national conferences (invited presentations)
2002- Chocorua Project receives Technical Excellence Award from the North American Lake Management Society
2003- UNH CE Maynard and Audrey Heckel Extension Fellow- ship awarded to LLMP
2004- Participatory Research Model of NH LLMP highlighted at National Water Quality Monitoring Conference
2005- LLMP Coordinator J. Schloss receives the prestigious Secchi Disk Award from the North American Lakes Management Society
2007- Lake friendly landscaping manual introduced receives praise from New Hampshire agencies and waterfront landowners.
2008- NH LLMP's 30 th year of sampling NH lakes!

We are excited by the results of teaming up students, educators and local lake residents through our Multidisciplinary Lakes Management course and our summer Community Mapping with GIS and Watershed Ecology courses that are held annually (the two latter mentioned courses are for educators, community leaders and other interested persons). Some of the lake management recommendations made as part of the student coursework requirements have been successfully implemented by lake associations.

We continue the research initiated by collaborators Dr. John Sasner and Dr. Jim Haney focusing on how watershed development and our activities on the landscape play a role in creating potentially toxic algae blooms. Analogous to the ‘red tide’ of estuaries, certain blue-green algae (microscopic bacteria) can produce toxins that are health risks to animals and humans.

Recent interest in the success of our NH LLMP participatory science research model has resulted in invited presentations at national conferences and provided the basis of a series of articles in the Volunteer Monitor, the national newsletter with a distribution of over 10,000. We continue to be listed as a model citizen-monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability. To

NH LLMP Directly involved with the Initiation,
Expansion or Support of Volunteer
Programs in 24 States.



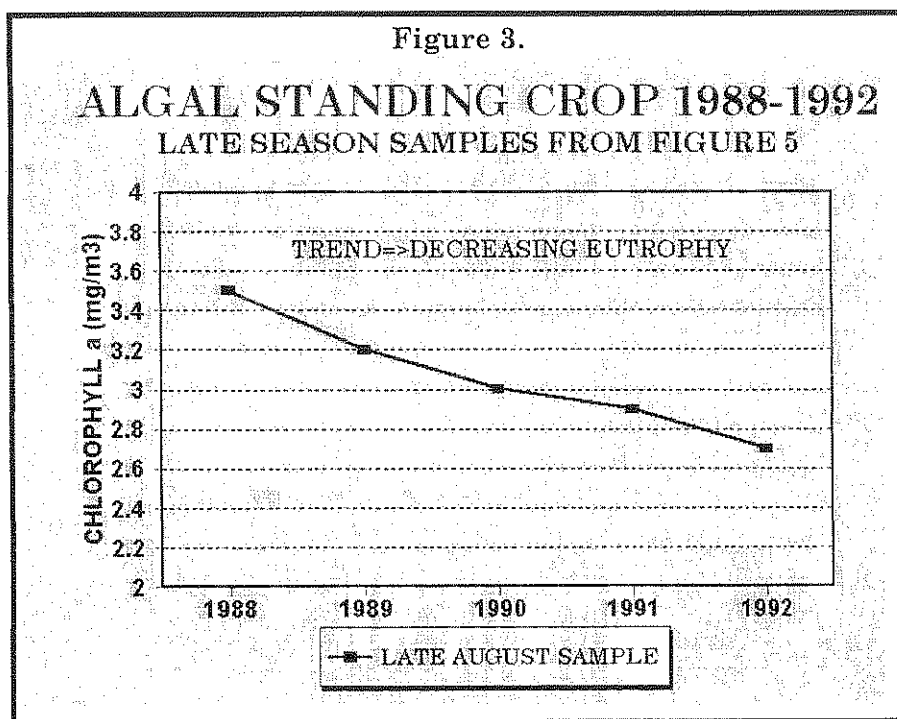
date, the approach and methods of the NH LLMP have been adopted by new or existing programs in twenty-four states and eleven countries (Figure 2)!

Importance of Long-term Monitoring

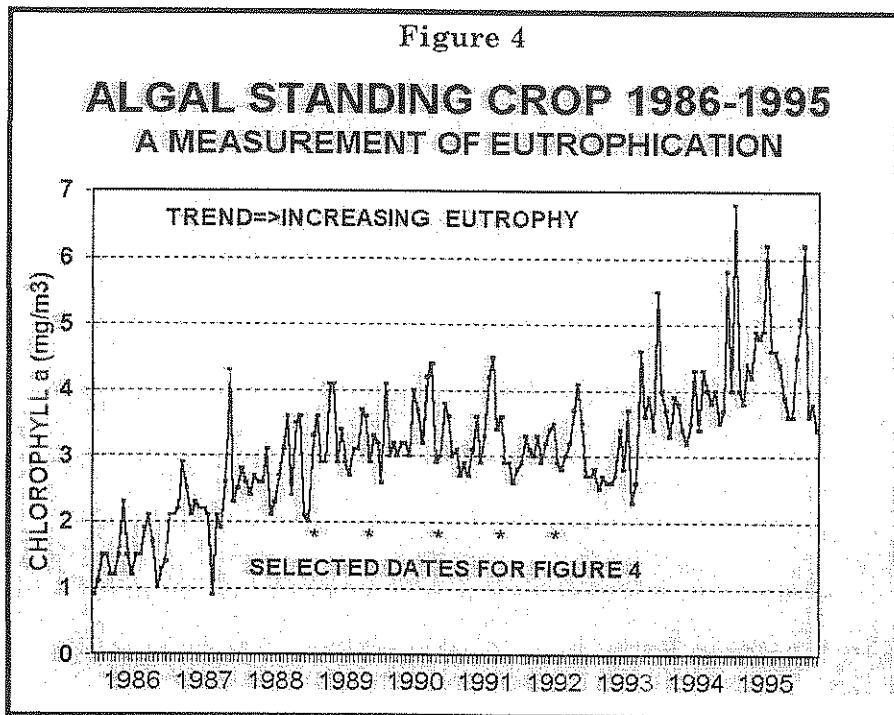
A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For over two decades, weekly data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

Consider the hypothetical data depicted in Figure 3. Limiting sampling of only once a year during August, from 1988 to 1992, produced a plot suggesting a decrease in eutrophication. However, the actual long-term trend of the lake, increasing eutrophication, can only be clearly discerned by frequent sampling over a ten-year period (Figure 4). In this instance, the information necessary to distinguish between short-term fluctuations, the "noise", and long-term trends, the actual "signal", could only be accomplished through the frequent collection of water quality data over many years. To that end, the establishment of a long-term database was essential to determining trends in water quality.



The number of seasons it takes to distinguish between the “noise” and the signal is not the same for each lake. Evaluation and interpretation of a long-term database will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, predictions of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.



There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it seems that one week's data does not differ from the next week's data, but every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Effort

The primary purpose of annual lake reporting is to discuss results of the current monitoring season with emphasis on current conditions of New Hampshire lakes including the extent of eutrophication and the lakes' susceptibility to increasing acid precipitation. If you have additional water quality concerns, we advise the lake association to contact our program staff to discuss additional monitoring options. When applicable we also strive to place the recent results into a historical context using past NH LLMP data as well as historical data from other sources. This information is part of a large data base of historical and more recent data compiled and entered onto our computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's through the 1950's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **CFB/FBG** surveys. However, care

must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

ACKNOWLEDGMENTS

2008 was the twenty-sixth year Lake Winnepesaukee (Alton) participated in the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 2, while Dr. Klaus Bie-mann again acted as liaison to the **Center for Freshwater Biology (CFB)**. The **CFB** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join the Alton water quality monitoring effort in 2009 and expand upon the current database. Funding for the water quality monitoring program was provided by the Town of Alton and by a few lake-shore associations in the Town of Alton.

**Table 2: Lake Winnepesaukee
Volunteer Monitors (2008)**

Site	Monitor Name
22A Alton	William & Jean Smith
24 Alton	Richard Jones
25 Alton	Paul Richardson
25 Alton	Doug Mills
26 Alton	Beverly & Richard DiVaio
Dellings	Katherine Cima

The **Center for Freshwater Biology** is a not-for-profit research program coordinated by Jeffrey Schloss and Robert Craycraft. Members of the **CFB** summer field team included William Finley, Gabrielle Hodgman, Lejla Kadic and Susan Wilderman while Jessy Klotzer provided additional assistance in the fall analyzing, compiling and organizing the water quality data.

The **CFB** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office and storage space while the College of Life Sciences and Agriculture provided laboratory facilities and additional storage space. The **CFB** would like to thank the **Caswell Family Foundation** for their continued generosity in providing long-term support for undergraduate assistantships while additional support for administering the **NH LLMP** comes from the **United States Department of Agriculture Cooperative State Research, Education and Extension Service** through support from the New England Regional Water Quality Program (<http://www.usawaterquality.org/newengland/>).

Participating groups in the **LLMP** include: Acton-Wakefield Watershed Alliance, Green Mountain Conservation Group, North River Lake Monitors, the associations of Baboosic Lake, Bow Lake Camp Owners, Chocorua Lake, Conway Lake Conservation, Crystal Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnepesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Swains Lake, Lake Wentworth, Winnisquam Drive, and the towns of Al-

ton, Amherst, Enfield, Madison, Meredith, Merrimack, Milton, Strafford and
Wolfeboro.

WINNIPESAUKEE (ALTON)

WATER QUALITY MONITORING (2008)

A volunteer based water quality monitoring was instituted on Lake Winnepesaukee (Alton) in 1983 to track long-term water quality trends and was expanded to identify water quality threats within the Lake Winnepesaukee watershed. This pro-active approach, dedicated to educating the public and municipal officials through the collection of quantitative baseline data, will help ensure that Lake Winnepesaukee continues to be a natural resource asset for future generations.

2008 Water Quality Data

Water Quality monitoring continued in Lake Winnepesaukee (Alton) during the “summer growing season” that spanned from April 22 through October 15, 2008. Water quality monitoring focused on the collection of water quality data at five deep sampling locations that provide insight into the overall condition of Lake Winnepesaukee (Alton). The 2008 Lake Winnepesaukee (Alton) water quality data continued to exhibit conditions that are characteristic of a clear lake that experiences short-term periods of reduced water transparency and periods of increased algal growth (greenness).

Water transparency measurements are collected with a standardized eight inch diameter black and white disk that is lowered into the water column while looking through a view tube (that emulates a snorkel mask) until it can no longer be seen. The Lake Winnepesaukee (Alton) water transparency measurements were high during the summer months and included a maximum visibility of 24.8 feet (10.1 meters) on September 17, 2008.

The amount of microscopic plant growth (visually detectible as golden or green water) remained low to moderate during the summer months and remained below nuisance levels. The total phosphorus (nutrient) concentrations were generally low at each of the deep sampling locations and corresponded to the low to moderate levels of microscopic plant growth.

Dissolved oxygen concentrations, required for a healthy fishery, remained high through the water column when measured on June 19. Current and historical dissolved oxygen data collected at the Alton sampling locations are sufficient to support a self-sustaining cold water fishery.

Lake acidity, measured as pH, was near neutrality and remained within the tolerable range for most aquatic organisms.

A more complete summary of the 2008 Lake Winnepesaukee (Alton) water quality monitoring data is included in the section “Lake Winnepesaukee (Alton) – 2008 Executive Summary”.

Common Concerns among New Hampshire Lakes

Many lakeshore property owners express concerns that increased aquatic plant "weed" growth and the amount of slime that coats the lake bottom in the shallows has been steadily increasing over the years. While quantitative data have not been generated to support these assertions in Lake Winnepesaukee, these are common concerns that have been expressed by residents throughout New Hampshire. As the lakeshore and the surrounding uplands are converted from a well forested landscape to a more suburbanized setting, more nutrients oftentimes enter the lake and in turn promote plant growth. Keep in mind, the same nutrients that stimulate growth of our lawns will also stimulate growth in our lakes. Nutrients can originate from a number of sources within the Lake Winnepesaukee watershed that include septic system effluent, lawn fertilizer runoff and sediment washout. While some nutrient loading will occur naturally even in our most remote New Hampshire Lakes, there are steps you can take to minimize nutrient runoff, that increases microscopic plant growth (greenness), contributes to the slimy coatings we find on rocks along our beaches and that is conducive to the formation of new, or expansion of existing weed beds around the periphery of Lake Winnepesaukee.

Recommendations for Healthy Lakeshore and Streamside Living

- Encourage shoreside vegetation and protect wetlands - shoreside vegetation (also known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality. Shore-line vegetation grown tall will also discourage geese and shade the water reducing the possibility of aquatic weed recruitment.
- Limit fertilizer applications - fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shore-line and can also produce unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are dangerous when ingested. Use low maintenance grasses such as fescues that require less nutrients and water to grow. After a lawn is established a single application of fertilizer in the late fall is generally more than adequate to maintain a healthy growth. Oftentimes a simple pH adjustment will do more good and release nutrients already in the soils.
- Limit organic matter loading - organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather exces-

sive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

- Limit the loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify substances and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities which favor the transport of a greater load of suspended and dissolved pollutants into your lake.
- Discourage the feeding ducks and geese – ducks and geese that are locally fed tend to concentrate around the known food source and can result in localized water quality problems. Waterfowl quickly process food into nutrients that are capable of stimulate microscopic plant “algal” growth. Ducks and Geese are also host to the parasite responsible for swimmers itch. While not a health threat, swimmers itch is very uncomfortable.
- Maintain Septic Systems - faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes in the summer. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly. Inspect your system on a timely basis and pump out the septic tank every three to five years depending on tank capacity and household water use.

Note: Consult materials such as those listed below, for further guidance on assessing and implementing corrective actions that can maintain or improve the quality of surface and subsurface (septic) runoff that may otherwise impact water quality.

- Pipeline: Summer 2008 Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality. http://www.nesc.wvu.edu/pdf/WW/publications/pipline/PL_SU08.pdf
- Landscaping at the Water's Edge: an Ecological Approach. \$20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824. <http://extension.unh.edu/resources/>
- Integrated Landscaping: Following Nature's Lead. \$20.00/ea University of New Hampshire Cooperative Extension Publications Center, Ne-

smith Hall, 131 Main Street, Durham NH 03824
<http://extension.unh.edu/resources/>

- New Hampshire Department of Environmental Services fact sheet series
(all topics)
<http://des.nh.gov/organization/commissioner/pip/factsheets/index.htm>

LAKE WINNIPESAUKEE (ALTON)

2008 EXECUTIVE SUMMARY

Water quality data were collected by the Lake Winnepesaukee (Alton) volunteer monitors between April 22 and October 17, 2008 while supplemental water quality data were collected by the Center for Freshwater Biology field team on June 19, 2008.

Generally speaking, the 2008 Alton water quality remained excellent as summarized in Table 3; the 2008 Alton water clarity was high while the microscopic plant (greenness) and the total phosphorus (nutrient) concentrations were generally low and remained below nuisance levels. On a seasonal basis, the Alton water clarity was generally shallowest among sampling sites, during the month of May; and followed the period of spring snowmelt and above average February, March and April precipitation that is commonly associated with shallower water transparency measurements. *Refer to the section "Climate Summary - 2008" for a discussion of the relationship between rainfall and water quality.*

Water quality data collected in the general vicinity of Alton/Alton Bay, Long Island, Meredith Bay and Moultonboro Bay were compared among regions to examine the water quality variations around Lake Winnepesaukee (Figure 9). The 2008 seasonal Lake Winnepesaukee (Alton) water clarity remained high, relative to the other locations around the lake, while the amount of microscopic plant growth (measured as chlorophyll α) in and around Alton was similar to the levels documented near Long Island and in southern Moultonborough during the 2008 sampling season (Figures 29 and 30).

The following section discusses the 2008 and historical Lake Winnepesaukee (Alton) water quality data. *Refer to Appendix A for a complete listing of the 2008 Alton water quality data and refer to Appendix B for an overview of the Box and Whisker plots that are included in this annual report.*

Table 3: 2008 Lake Winnepesaukee (Alton) Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Pristine"	Mesotrophic "Transitional"	Eutrophic "Enriched"	Lake Winnepesaukee Alton Average (range)	Lake Winnepesaukee Alton Classification
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	7.8 meters (range: 5.4 - 10.1)	Oligotrophic
Chlorophyll a (ppb)	< 3.0	3.0 - 7.0	> 7.0	1.5 ppb (range: 0.6 - 3.6)	Oligotrophic
Phosphorus (ppb)	< 15.0	15.0 - 25.0	> 25.0	8.1 ppb (range: 3.3 - 66.7)	Oligotrophic

* Total Phosphorus data were collected in the surface waters (epilimnion) by the volunteer monitors.

1) **Water Clarity (measured as Secchi Disk transparency) – The 2008**

Alton water clarity values were high and consistently remained above the transparency of 4 meters that is considered the boundary between an unproductive "pristine" and more nutrient enriched "transitional" New Hampshire lake (Tables 3 & 4 and Figures 11-18. The shallowest water transparency measurement of 5.4 meters (17.7 feet)

was documented at Site 24 Alton on May 6, 2008 (Figures 13 and 29).

The 2008 median Secchi Disk transparencies documented at each of the deep Alton sampling locations decreased (i.e. less clear water) relative to the 2007 median values at Sites 22A, 24, 25 and 26 (Figures 19, 21, 23 and 25).

Table 4: 2008 Water Clarity data summary for the Lake Winnepesaukee deep sampling stations.

Site	Seasonal Average Water Transparency (meters)
22A Alton	7.9 meters (range: 5.5 – 10.0)
24 Alton	7.8 meters (range: 5.4 – 9.1)
25 Alton	7.5 meters (range: 5.5 – 9.0)
26 Alton	8.8 meters (range: 7.8 – 10.1)
Dellings Cove	7.3 meters (range: 6.6 – 7.9)

2) **Microscopic plant abundance “greenness” (measured as chlorophyll *a*) – The 2008 seasonal chlorophyll *a* concentrations remained below the concentration of 3 parts per billion (ppb) that is considered the boundary between a nutrient poor and more nutrient enriched "greener" lake (Table 5 and Figures 11, 13, 15, 17 and 30).**

The 2008 median chlorophyll *a* concentrations documented at Sites 22A Alton, 24 Alton and 25 Alton remained low and well within the range of historical values documented since 1983 for the respective sampling locations (Figures 20, 22 and 24). The chlorophyll *a* concentrations documented at . On the other hand, the median chlorophyll *a* concentration documented at Site 26 Alton was the highest value (i.e. greenest water) documented since water quality monitoring was initiated at the site in 1983 (Figure 26).

Table 5: 2008 Chlorophyll *a* data summary for the Lake Winnepesaukee deep sampling stations.

Site	Seasonal Average Chlorophyll <i>a</i> (ppb)
22A Alton	1.4 ppb (range: 0.7 – 2.1)
24 Alton	2.0 ppb (range: 1.4 – 3.6)
25 Alton	1.5 ppb (range: 0.9 – 2.9)
26 Alton	1.2 ppb (range: 0.6 – 1.5)
Dellings Cove	0.9 ppb (range: 0.6 – 1.1)

3) **Background (dissolved) water color : often perceived as a “tea” color in more highly stained lakes – The 2008 Alton dissolved color concentration averaged 9.8 chloroplatinate units (cpu) and fell within the classification of a slightly “tea” colored lake (Table 6). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the**

natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality.

Dissolved color concentrations tended to be higher early in the year following the period of spring snowmelt and the heavy April rains (Figures 12, 14, 16 & 18).

Table 6. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Range	Classification
0 - 10	Clear
10 - 20	Slightly colored
20 - 40	light tea color
40 - 80	tea colored
> 80	highly tea colored

4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire Lakes. - Total phosphorus concentrations, measured in the surface waters (epilimnion), were generally low when collected by the Alton volunteer monitors and by the University of New Hampshire Center for Freshwater Biology field team members. The 2008 Alton total phosphorus values ranged from 3.3 to 66.7 parts per billion (ppb) and generally remained below the concentration of 15 ppb that is considered the boundary between an unproductive and a moderately productive New Hampshire lake (Table 3). A total phosphorus maximum of 66.7 parts per billion was documented at Site 24 Alton (June 13, 2008) and was significantly higher than the other measurements documented during the 2008 sampling season. While it is possible the June 13 total phosphorus sample was an indication of a short-term runoff event it is also possible the sample was contaminated. Further sampling will continue to track total phosphorus concentrations and assess whether localized water quality problems exist.

5) Resistance against acid precipitation (measured as total alkalinity)

- The 2008 seasonal average Lake Winnepesaukee (Alton) alkalinity measured 6.7 milligrams per liter (mg/l) and is considered typical of a lake with a moderate vulnerability to acid precipitation according to the standards developed by the New Hampshire Department of Environmental Services (Table 7). Generally speaking, the geology of the region does not contain the mineral content (i.e. limestone) which increases the buffering capacity in our surface waters. Thus, lakes in the vicinity (Merrymeeting Lake and Lake Wentworth) naturally have low alkalinities.

Table 7. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services

Range	Classification
< 0	Acidified
0 -2	Extremely Vulnerable
2.1 - 10.0	Moderately Vulnerable
10.1 - 25.0	Low Vulnerability
> 25.0	Not Vulnerable

6) Dissolved salts: measured as specific conductivity - Specific Conductivity levels, documented in Lake Winnepesaukee (Alton) by the Center for

Freshwater Biology, were low and ranged from 64 to 70 micro-Siemans per centimeter ($\mu\text{S}/\text{cm}$) when measured on June 19, 2008. High specific conductivity values can be an indication of problem areas around a lake where failing septic systems, heavy fertilizer applications and sedimentation are contributing “excessive” nutrients that are subsequently flushed into the lake. Such values can also be an indication of heavy road salt applications within the Lake Winnepesaukee watershed. The specific conductivity data did not suggest any gross water quality problems on the June 19, 2008 sampling date.

8) **Temperature and dissolved oxygen profiles** – Temperature profiles collected by the volunteer monitors indicate Lake Winnepesaukee (Alton) becomes stratified into three distinct thermal layers during the summer months; a warm upper water layer, the **epilimnion**, overlies a layer of rapidly decreasing temperatures, the **thermocline**, followed by a deep cold-water layer, the **hypolimnion**. The formation of thermal stratification limits the replenishment of oxygen in the deeper waters and under certain conditions can correspond to oxygen depletion near the lake-bottom.

9) **Dissolved oxygen concentrations required for a healthy fishery** – Dissolved oxygen concentrations documented by the **Center for Freshwater Biology** on June 19, 2008 remained high throughout the water column (Figure 31). The 2008 Lake Winnepesaukee (Alton) dissolved oxygen concentrations remained above the concentration of 5 milligrams per liter (mg/l) that is considered the minimum oxygen concentration required for the successful growth and reproduction of most coldwater fish that include trout and salmon. Generally speaking, the year 2008 dissolved oxygen concentrations were within the optimal range for the Lake Winnepesaukee fishery and were capable of supporting salmonoid populations.

COMMENTS AND RECOMMENDATIONS

Alton Specific Comments/Recommendations:

1) We recommend continued water quality sampling near the Alton Bay Pavillion/Town Docks on a monthly basis during the 2009 sampling season. Water quality data collected in 2007 and 2008 have documented water quality variations between the more embayed Pavillion sampling site and Site 25 Alton. The Pavillion site is relatively shallow (7 meters/approximately 23 feet) and the lake receives an appreciable contribution of water from the Merrymeeting Marsh wetland complex. Sampling on a monthly basis would better assess the current condition of this area of the lake and would help discern whether localized water quality problems exist.

2) Expanded monitoring of near-shore sampling and/or stream sampling is recommended to better assess whether localized water quality variations exist in and around Lake Winnepesaukee (Alton). The supplemental near-shore and tributary sampling would facilitate the targeting of resources (i.e. money and volunteer hours) to the most critical areas within the watershed where future monitoring and corrective efforts should be directed. Expanded water quality monitoring could be as simple as collecting additional near-shore/tributary total phosphorus or chlorophyll a samples or could involve the expansion to the collection of additional water quality parameters such as specific conductivity or turbidity measurements. Advanced water quality monitoring efforts might also include more in-depth shoreline/watershed surveys aimed at visually identifying the land-use patterns and potential problem areas within the Lake Winnepesaukee drainage basin. If you are interested in discussing additional water quality monitoring options that would meet your needs please contact Bob Craycraft @ 862-3696 or via email, bob.craycraft@unh.edu.

General Comments/Recommendations:

1) We recommend that each participating lake association, including the Winnepesaukee Lake Association, continue to develop its database on lake water quality through continuation of the long-term monitoring program. The database currently provides information on the short-term and long-term cyclic variability that occurs in Winnepesaukee Lake while continued monitoring would enable more reliable predictions of both short-term and long-term water quality trends.

2) We recommend initiating lake sampling early in the season (April/May) to document Alton Bay's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll α , dissolved color, Secchi Disk transparency and total phosphorus measurements.

3) Frequent "weekly" water quality samples, necessary to assess the current condition of Alton Bay, should continue to be collected whenever possible. Continued sampling of chlorophyll α , Secchi Disk transparency, dissolved color, alkalinity and total phosphorus samples will be useful to track variations in nutrient loading during the summer months.

Climatic Summary - 2008

Water Quality and the Weather

Water quality variations are commonly observed over the course of the year and among years in our New Hampshire lakes, ponds, wetlands and streams. The most commonly noticed changes are those associated with decreasing water clarities, increasing algal growth (greenness), and increasing plant growth around the lake's periphery. Over the long haul, changes such as these are attributed to a lake's natural aging process that is referred to as "**eutrophication**". However, short-term water quality changes such as those mentioned above are often encountered even in our most pristine lakes and ponds. These water quality changes often coincide with variations in weather patterns such as precipitation and temperature fluctuations, and even variations in the sunlight intensity which can accelerate or suppress the photosynthetic process.

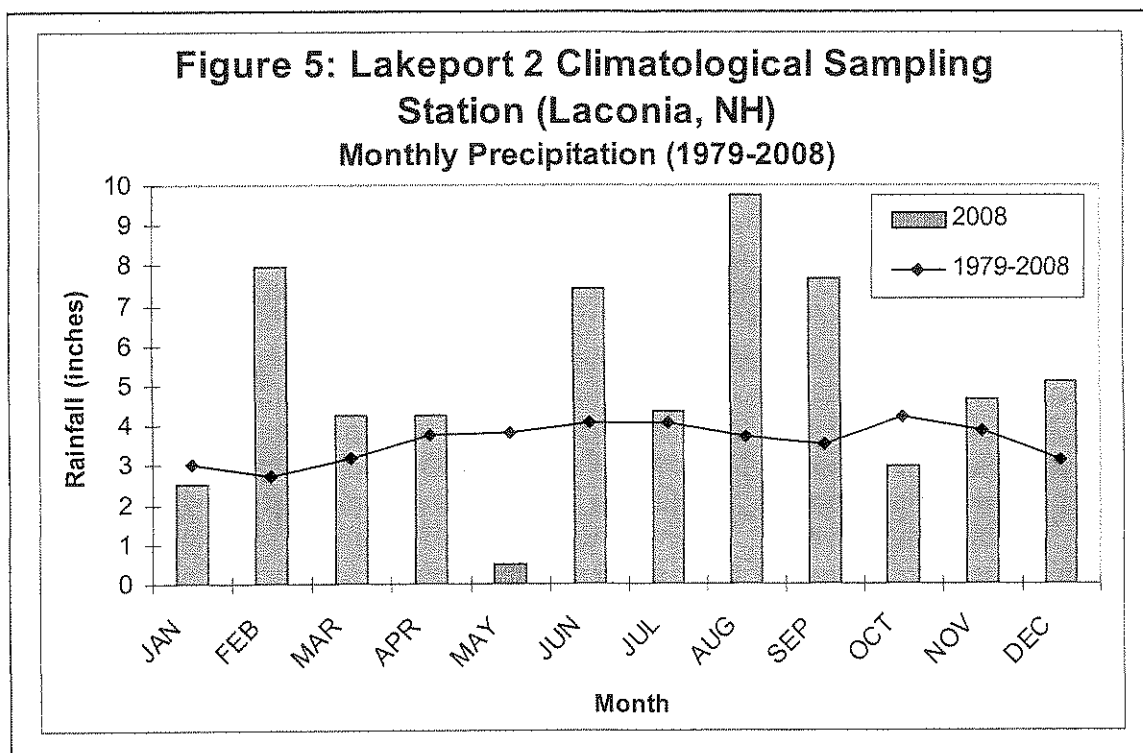
Climatic "swings" can have a profound effect on water quality, sometimes positive and other times negative. For instance, 1996 was a wet year relative to other years of **LLMP** water quality monitoring. This translated into reduced water clarities, elevated microscopic plant "algal" growth and increased total phosphorus concentrations for most participating **LLMP** lakes. "Excessive" runoff associated with wet periods often facilitates the transport of pollutants such as nutrients (including phosphorus), sediment, dissolved colored compounds, as well as toxic materials such as herbicides, automotive oils, etc. into water bodies. As a result, lakes often respond with shallower water clarities and elevated algal abundance (greenness) during these periods as evidence by historical monitoring through the **NH LLMP**. Similarly, short-term storm events can have a profound effect on the water quality. Take for instance the "100 year storm" (October 21-22, 1996) that blanketed southern New Hampshire with approximately 6 inches of rain over a 30-hour period. This storm resulted in increased sedimentation and organic matter loading into our lakes as materials were flushed into the water bodies from the adjacent uplands. Likewise, the heavy rains that saturated the soil and resulted in flood conditions in June 1998 (heaviest rains occurring on June 12 and 13) resulted in significantly shallower water transparency readings in the weeks to months that followed. While events such as the October 1996 and the June 1998 storms are short lived, they can have a profound effect on our water quality in the weeks to months that follow, particularly when nutrients that stimulate plant growth are retained in the lake.

NH LLMP data collected during dry years such as 1985 and 2001, on the other hand, have coincided with improved water quality for many New Hampshire lakes. Reduced pollutant transport into the lake often results in higher water quality measured as deeper water transparencies, lower microscopic plant "algae" concentrations and lower nutrient concentrations. Do all lakes experience poorer water quality as a result of heavy precipitation events? Simply stated, the answer is no. While most New Hampshire lakes are characterized by reduced water clarities, increased nutrients and elevated plant "algal" concentrations following periods, or years, of heavy precipitation, a handful of lakes actually benefit from these types of events. The water bodies that improve during wet periods are generally lakes characterized by high nutrient concentrations and high "algal" concentrations that are diluted by watershed runoff and thus benefit during periods, or years, of heavy rainfall. However, these more nutrient en-

riched lakes remain susceptible to nutrients entering the lake from seepage sources such as poorly functioning septic systems.

Precipitation (2008)

The 2008 annual precipitation (reported as “rainfall” water equivalent) measured 61.47 inches and was significantly higher than the 30 year, 1979-2008, average of 43.08 inches (note: precipitation data are reported for the Lakeport 2 Climatological sampling station located in Laconia New Hampshire: 43°33'N and 71°28'W). With the exception of below average rainfall during the months of January, May and October, monthly precipitation totals were near or above normal (Figure 5). Heavy precipitation during the month of February, the associated snowpack accumulation and above average March and April precipitation resulted in periods of heavy spring watershed runoff. Precipitation decreased precipitously in May and the monthly precipitation total of 0.48 inches was the lowest May rainfall total documented over the past 30 years. The lack of May rainfall coincided with the streams returning to baseflow (low flow) conditions. Atypically high periods of rainfall were again documented during the months of June, August and September during which the monthly precipitation totals exceeded 7 inches. In-stream water quality data collected at select Newfound Lake tributary inlets during an August 11 precipitation event (1.91”) included turbidity and total phosphorus concentrations that were nearly two orders of magnitude (100x) above baseline concentrations. Heavy storm events, such as that documented on August 11, increase the nutrient and sediment load into New Hampshire lakes and streams and are associated with reduced seasonal water transparency in many of our New Hampshire Lakes. Below average precipitation characterized the month of October followed by a return to near to above average precipitation during the months of November and December.

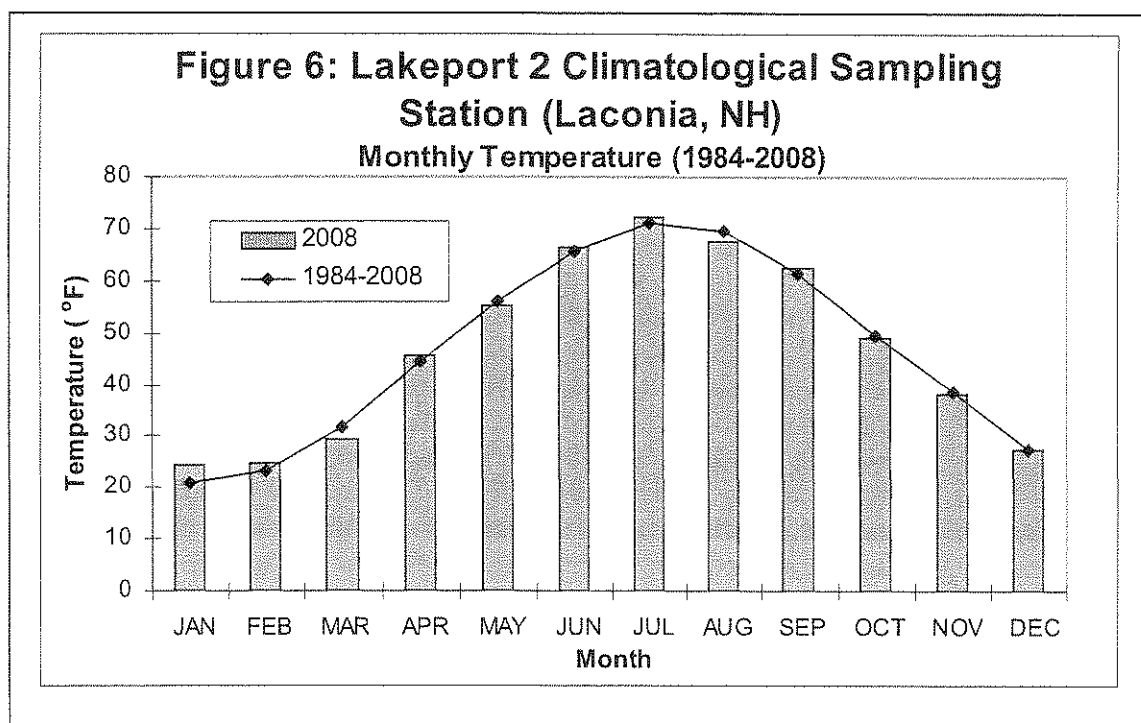


Temperature (2008)

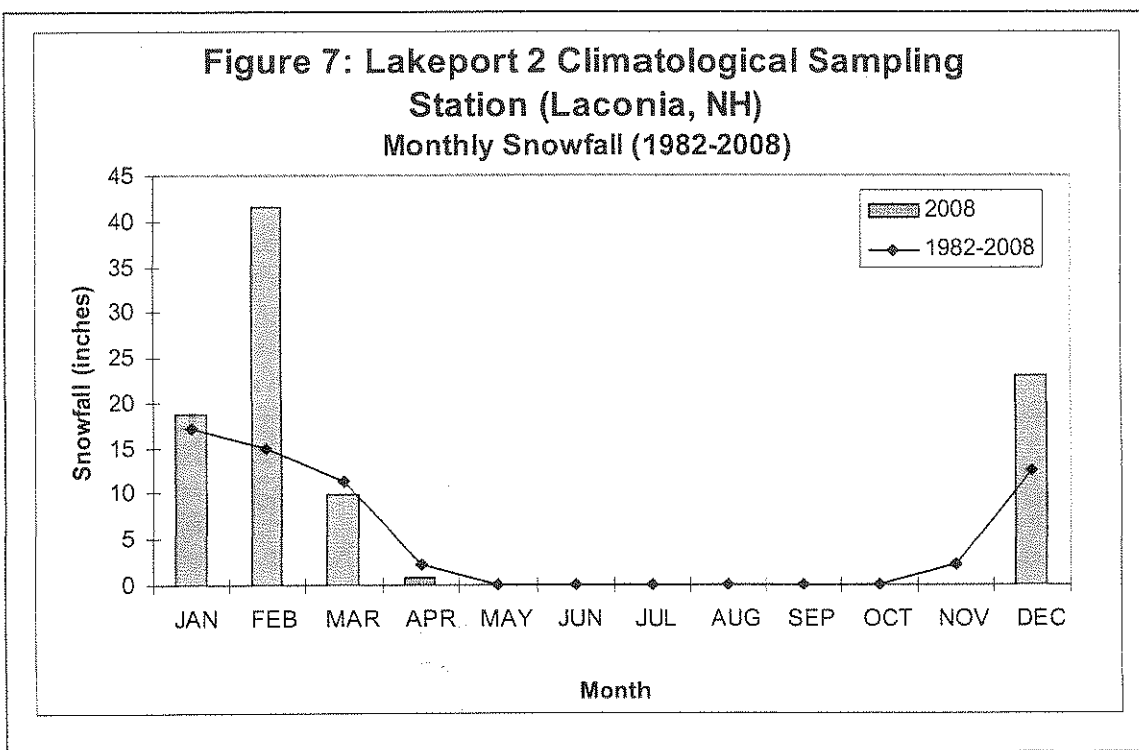
Similar to the impact of precipitation extremes, temperature extremes can have far reaching effects on the water quality, particularly early in the year and during the summer months. Atypically warm periods can account for a rapid snowpack melt resulting in flooding and a massive influx of materials (e.g. nutrients, sediments) into our lakes during the late winter and early spring months. Early spring runoff periods coincide with minimal vegetative cover (that acts as a pollutant filter and soil stabilizer) and thus leaves the landscape highly susceptible to erosion. As we progress into the summer months, atypically warm periods can enhance both microscopic “algal” and macroscopic aquatic “weed” plant growth. During the summer growing season, above average temperatures often result in algal blooms that can reach nuisance proportions under optimal conditions. These nuisance blooms can include surface algal “scums” that cover the lake and wash up on the windward lakeshores.

During years such as 1994 and 1995, when above average temperatures exemplified the summer months, participating NH LLMP lakes were generally characterized by increased algal concentrations, particularly in the shallows, where filamentous cotton-candy-like clouds of algae (i.e. *Mougeotia*) flourished. Other NH LLMP lakes had increased algal growth (greenness) and shallower water transparencies during these “hot” periods.

The January 2008 average monthly temperature was over three degrees warmer than the twenty-five year monthly average while the March 2008 average monthly temperature was below the twenty-five year monthly average (Figure 6). The accumulation of snowpack during the cold months of January and February (Figure 7), coupled with atypically heavy February precipitation (Figure 5) and below average March temperatures (Figure 6), translated into the potential for an intense period of spring runoff. As temperatures increased in March, the snowpack accumulations began to melt and contributed to heavy periods of runoff in mid to late March and during the month of



April. The average monthly temperatures documented between April and December, with the exception of an atypically warm month of July and the below average August temperature, were near normal (Figure 6).



Water Quality Impacts

Water Transparency and Dissolved “tea” Colored Water

As previously mentioned, shallower water transparency readings are characteristic of most New Hampshire lakes during wet years and following short term precipitation events. Wet periods often coincide with greater concentrations of dissolved “tea” colored compounds (dissolved organic matter resulting from the breakdown of vegetation and soils) washed in from surrounding forests and wetlands. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Data collected by the **Center for Freshwater Biology (CFB)** since 1985 indicate most lakes are characterized by higher dissolved “tea” colored water during wet years relative to years more typical in terms of annual precipitation levels. In some of our more highly “tea” colored lakes the early spring months are also characterized by higher dissolved color concentrations, relative to mid-summer levels, due to the heavy runoff periods that flush highly colored water into our lakes during the period of spring snowmelt and following heavy spring rains.

Sediment Loading

Sediments are continuously flushed into our lakes and ponds during periods of heavy watershed runoff, particularly during snowmelt and again during and following sporadic storm events during the summer and fall months. Many New Hampshire lakes experience water clarity decreases following storm events such as those described above. Lakes, ponds and rivers are particularly susceptible to sediment loadings in the early spring months when vegetated shoreline buffers, often referred to as riparian buffers, are reduced. With limited vegetation to trap sediments and suspended materials, a high percentage of the particulate debris and dissolved materials are flushed into the lake. Human activities such as logging, agriculture, construction and land clearing can also increase sediment displacement during and following heavy storm events throughout the year. These activities are often associated with excessive sediment loading in many of our lakes and ponds. As these materials (sediments) are transported into surface waters they can degrade water quality in a number of ways. When fine sediments (silt) enter a lake they tend to remain in the water column for relatively long periods of time. These suspended sediments can be abrasive to fish gills, ultimately leading to fish kills. Suspended sediments also reduce the available light necessary for plant growth that can result in plant die-offs and the subsequent oxygen depletion under extreme conditions.

As sediments settle out of the water column they can smother bottom dwelling aquatic organisms and fish spawning habitat. As the dead materials begin to decay the result can be noxious odors as well as stimulation of nuisance plant growth (i.e. scums along the lake-bottom; new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as water milfoil (*Myriophyllum heterophyllum*) will generally regenerate more rapidly than more favorable plant forms. This can result in more problematic weed beds than those present before the disturbance. Habitat changes associated with the accumulation of fine sediments and associated "muck" might also favor increased nuisance plant growth in the future. Another unfavorable attribute of sediment loading is that the sediments tend to carry with them other forms of contaminants such as pathogens, nutrients and toxic chemicals (i.e. herbicides and pesticides).

Early symptoms of excessive sediment runoff include deposits of fine material along the lake-bottom, particularly in close proximity to tributary inlets and disturbed regions previously discussed (i.e. construction sites, logging sites, etc.). Silt may be visible covering rocks or aquatic vegetation along the lake-bottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lake-bottom you might notice a change in the weed composition reflecting a change in the substrate type (note: aquatic plants will display natural changes in abundance and distribution, so be careful not to jump to hasty conclusions). If excessive sediment loading is suspected, take a closer look in these areas and assess whether or not the change is associated with sediment loading (look for the warning signs discussed above) or whether the changes might be attributable to other factors.

Nutrient Loading

Nutrient loading is often greatest during heavy precipitation events, particularly during the periods of heavy watershed runoff. Phosphorus is generally considered the limiting nutrient for excessive plant and algal growth in New Hampshire lakes. Elevated phosphorus concentrations are generally most visible when documented in our

tributary inlets where nutrients are concentrated in a relatively small volume of water. Much of the phosphorus entering our lakes is attached to particulate matter (i.e. sediments, vegetative debris), but may also include dissolved phosphorus associated with fertilizer applications and septic system discharge.

Microscopic "Algal" and Macroscopic "Weed" Plant Growth

Historical Lakes Lay Monitoring Program data indicate most lakes experience "algal blooms" during years with above average summer temperatures (June, July and August) while years with heavy precipitation are also associated with an increased frequency and occurrence of "algal blooms". "Algal blooms" are often green water events associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". During some years, such as 1996, the "algal blooms" are predominantly green water events composed of algae distributed within the water column. New Hampshire lakes were particularly susceptible to algal blooms in 1996 as a function of the heavy runoff associated with an atypically wet year. Wet years such as 1996 can be particularly hard on lakes where excessive fertilizer applications, agricultural practices and construction activities favor the displacement of nutrients into surface waters. The occasional formation of certain algal blooms is a naturally occurring phenomenon and is not necessarily associated with changes in lake productivity. However, increases in the occurrence of bloom conditions can be a sign of eutrophication (the "greening" of a lake). Shifts from benign (clean water) forms to nuisance (polluted water) cyanobacterial forms such as *Anabaena*, *Aphanizomenon* and *Oscillatoria*, can also be a warning sign that improper land use practices are contributing excessive nutrients into the lake.

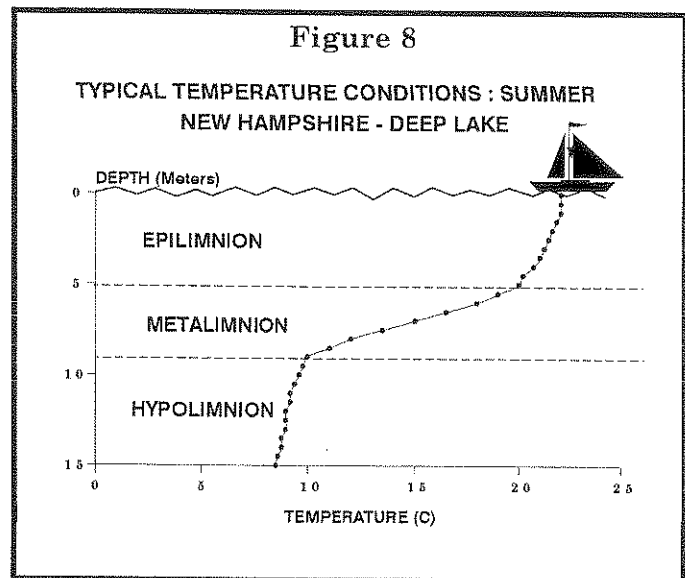
Filamentous cotton-candy-like "clouds" of the nuisance green algae, *Mougeotia* and related species, have been well documented in 1994 and 1995 when the temperatures during the months of June and July were well above normal. These algal "clouds" often develop within nearshore weed beds where they can be seen along the lake-bottom and tend to flourish during warm periods. During cooler years, this type of algal growth is kept "in check" and generally does not reach nuisance proportions. In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading.

DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Certain tests or sampling performed at the time of the optional **Center for Freshwater Biology** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (Figure 8). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.



Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes.

Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg m³ (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3 mg m³. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg m³ and 7 mg m³. Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an early indication of increased nutrient loading into the lake.

Turbidity *

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment runoff into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lake bottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase

drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (agriculture, logging, sediment erosion, septic systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

Soluble Reactive Phosphorus *

Soluble reactive phosphorus is a fraction of the (total) phosphorus that consists largely of orthophosphate, the form of phosphorus that is directly taken up by algae and that stimulates growth. Soluble reactive phosphorus is obtained by filtering a water sample through a fine mesh filter, generally a 0.45 micron membrane filter, which effectively removes the particulate matter from the sample. Soluble reactive phosphorus concentrations are thus less than, or equal to, the measured total phosphorus concentrations for a water sample.

Soluble reactive phosphorus typically occurs in trace concentrations while applications of fertilizers as well as septic system effluent can be associated with elevated concentrations. Knowledge of both the total phosphorus and the soluble reactive phosphorus is important to understanding the sources of phosphorus into a lake and to understanding the lake's response to the phosphorus loading. For instance, a lake experiencing soluble reactive phosphorus runoff from a fertilized field may exhibit immediate water quality decline (i.e. increased algal growth) while lakes experiencing elevated total phosphorus concentrations associated with sediment washout may not exhibit clear symptoms of increased nutrient loading for years.

Streamflow

Streamflow, when collected in conjunction with stream channel information, is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the alkalinity value, the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Center for Freshwater Biology** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in **micromhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (μS). Specific conductivity implies the measurements are standardized to the equivalent room temperature reading as conductivity will increase with increasing temperature.

Sodium and Chloride *

Low levels of sodium and chloride are found naturally in some freshwater and groundwater systems while high sodium and chloride concentrations are characteristic of the open ocean and are elevated in estuarine systems as well. Elevated sodium and chloride concentrations in freshwater or groundwater systems, that exceed the natural baseline concentrations, are commonly associated with the application of road salt. Sodium and particularly chloride are highly mobile and, relatively speaking, move into the surface and groundwater relatively unimpeded. Sodium and chloride concentrations can become elevated during periods of heavy snow pack melt when the salts are flushed into surface waters and have also been observed in elevated concentrations during the summer months when low flow conditions concentrate the sodium and chloride.

Road salt runoff is known to adversely impact roadside vegetation as is often-times evidenced by bleached (discolored) leaves and needles and in more extreme instances dead trees and shrubs. The United States Environmental Protection Agency (EPA) has set the standard for protection of aquatic life, both plants and animals, at 230 milligrams per liter (mg/l). The EPA has also established a secondary maximum contaminant level of 250 mg/l for both sodium and chloride, predominantly for taste, while the sodium advisory limit for persons with hypertension is 20 mg/l.

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumula-

tion is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only water-proofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

Indicator Bacteria *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

Total coliform includes all coliform bacteria that arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl

roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

Macroinvertebrates *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zoo-

plankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddis flies (Trichoptera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

Fish Condition

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

Understanding Lake Aging (Eutrophication)

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A common concern among New Hampshire Lakes Lay Monitoring Program (NH LLMP) participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant "algae" growth (detected as greener water), and water transparency decreases; what is known as **eutrophication**. Eutrophication is a natural process by which all lakes age and progress from clear pristine lakes to green, nutrient enriched lakes on a geological time frame of thousands of years. Much like the fertilizers applied to our lawns, nutrients that enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to naturally occurring attributes: watershed area relative to lake area, slope of the land surrounding the lake, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age, which ended about 10,000 years ago, we should have a natural continuum of lakes ranging from extremely pristine to very enriched.

Classification criteria are often used to categorize lakes into what are known as **trophic states**, in other words, levels of lake plant and algae productivity or "greenness" Refer to Table 4 below for a summary of commonly used eutrophication parameters.

Table 4: Eutrophication Parameters and Categorization

Parameter	Oligotrophic "pristine"	Mesotrophic "transitional"	Eutrophic "enriched"
Chlorophyll a (ug/l) *	<3.0	3.0-7.0	>7.0
Water Transparency (meters) *	>4.0	2.5-4.0	<2.5
Total Phosphorus (ug/l) *	<15.0	15.0-25.0	>25.0
Dissolved Oxygen (saturation) #	high to moderate	moderate to low	low to zero
Macroscopic Plant (Weed) Abundance	low	moderate	high

* Denotes classification criteria employed by Forsberg and Ryding (1980).

Denotes dissolved oxygen concentrations near the lakebottom.

Oligotrophic lakes are considered “unproductive” pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant “weed” growth, and high dissolved oxygen concentrations near the lake bottom. **Eutrophic** lakes are considered “highly productive” enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands of aquatic plants and very low dissolved oxygen concentrations near the lake bottom. **Mesotrophic** lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant “weed” growth and decreasing dissolved oxygen concentrations near the lake bottom.

Is a pristine, oligotrophic, lake “better than” an enriched, eutrophic, lake? Not necessarily! As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due to their natural attributes and in turn have aged more rapidly. This is not necessarily a bad thing as our best bass fishing lakes tend to be more mesotrophic to eutrophic than oligotrophic; an ultra-oligotrophic lake (extremely pristine) will not support a very healthy cold water fishery. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period that should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of once forested or agricultural lands are being developed, with the potential for increased sediment and nutrient loadings into our lakes, which augment the eutrophication process.

Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake’s “health”. A “healthy” lake, as far as eutrophication is concerned, is one in which the various aquatic plants and animals are minimally impacted so that nutrients and other materials are processed efficiently. We can liken this process to a well-managed pasture: nutrients stimulate the growth of grasses and other plants that are eaten by grazers like cows and sheep. As long as producers and grazers are balanced, a good amount of nutrients can be processed through the system. Impact the grazers and the grass will overgrow and nuisance weeds will appear, even if nutrients remain the same. In a lake, the producers are the algae and aquatic weeds while the grazers are the microscopic animals (**zooplankton**) and aquatic insects. These organisms can be very susceptible to a wide range of pollutants at very low concentrations. If impacted, the lake can become much more productive and the fishery will be impacted as well since these same organisms are an important food source for most fish at some stage of their life.

Development upon the landscape can negatively affect water quality in a number of ways:

- Removal of shore side vegetation and loss of wetlands - shore side vegetation (what is known as **riparian vegetation**) and wetlands provide a protective buffer that “traps” pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant ma-

terials are more likely to enter the lake and in turn, favor declining water quality.

- Excessive fertilizer applications - fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline producing unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins, which irritate the skin and under extreme conditions, are dangerous when ingested.
- Increased organic matter loading - organic matter (leaves, grass clippings, etc.) is a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.
- Septic problems - faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.
- Loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify pollutants and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities that favor the transport of a greater load of suspended and dissolved pollutants into your lake.

How can you minimize your water quality impacts?

- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess eventually draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody within the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake. Have your soil tested for a nominal fee (contact your county UNH Cooperative Extension Office for further information) to find out how much fertilizer and soil amendments are really needed. Sometimes just an application of crushed lime will release enough nutrients to fit the bill. If you do use fertilizer try to use low phosphorus, slow release nitrogen varieties. And

remember that under the current NH Comprehensive Shoreline Protection Act (CSPA) you cannot apply any fertilizers or amendments within 25 feet of the shore.

- Don't dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center. Do not fill in wetland areas. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in lake as it gets transported away by currents and wind).
- Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around \$10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation. Refer to:

Pipeline: Summer 2008 Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality.

http://www.nesc.wvu.edu/pdf/WW/publications/pipeline/PL_SU08.pdf

- Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge. Refer to:

Landscaping at the Water's Edge: an Ecological Approach. \$20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.

Integrated Landscaping: Following Nature's Lead. \$20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824

- Maintain shore side (riparian) vegetative cover when new construction is undertaken. For those who have pre-existing houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Refer to:

Landscaping at the Water's Edge: an Ecological Approach. \$20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.

Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire.

<http://www.nh.gov/oep/resourcelibrary/documents/buffershandbook.pdf>

- Review the New Hampshire Comprehensive Shoreland Protection Act (CSPA) if you have shoreland property. The CSPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the act or need further information contact the *Shoreline Protection Act Coordinator* at (603) 271-3503.

Lake Friendly Lawn Care

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Below is an expanded version of an article written by the author and published in the Spring 2009 "Lakeside", the newsletter of the NH Lakes Association.

The recent publication, "Landscaping at the Waters Edge: An ecological approach" from UNH Cooperative Extension (www.extension.unh.edu/publications) covers the importance of considering how you may landscape your shoreline property for both the improvement of water quality as well as the enhancement of your property. Lawns and lawncare, specifically for shoreline properties, are among the most popular requests for information. While the publication goes into much greater and more specific detail, the information below is a good start when considering lawns and their potential impacts to water quality.

There is often controversy and confusion regarding lawns on shoreland properties. Some consider lawns inconsistent with the natural shoreland ecology while others want to bring to their shoreland home the same look and feel as the neighborhoods in suburbia that they have grown up with. As all vegetation provides at least some water quality functions, a lawn managed in the proper way can still allow for stabilized soils, filtered water infiltration into the ground and some nutrient and pollutant capture. And as with all vegetation, lawns sequester carbon dioxide, produce oxygen and, by doing so, cool the planet. Thus, lawns still make a better alternative to pavement or patios which create greater runoff conditions and impede groundwater recharge. Of course, if managed improperly and located too close to the water, lawns and their care can add to pollutant and nutrient loading to our surface and ground waters, attract nuisance weeds and insect pests (and even big pests like Canadian Geese!), impact important plant and wildlife species, as well as greatly reduce the available potable water supply with their potential need for irrigation. So how might you maintain a lawn area to enjoy on your shoreland property (or any property for that matter) while minimizing your impacts to the water quality and natural ecology?

- **Everything in moderation**- We often hear from our health providers that moderation is the key to healthy living and the same holds true for natural systems. Questions to ask yourself here include: How much lawn or open space do we really need for our intended use? Do we need to have all of our open space as a monoculture of a single type of grass or can we live with a combination of grasses and groundcovers that match our use? There are many varieties of

grasses depending on the type and frequency of use (ie: occasionally picnicking to kids playing ball everyday) and site conditions (soils, sun exposure and slope). Recently developed fescues, for example, require less maintenance (water, mowing and fertilizing) and can even be obtained with symbiotic fungi in their roots that make the grass better resistant to pests and diseases. The best approach is a mix of grass species with even some other groundcovers and white clover (or another low growing legume to naturally supply nitrogen to the soil). Talk to your county Extension educator, landscaper, or garden center expert about your options.

- **Location, location, location-** Yes, the mantra of real estate agents also works well for lawns. Additional maintenance of a lawn, even when not excessive, can still threaten water quality. To make up for this residents might consider locating the lawn as away from the shore as possible and maintaining a significant buffer area downslope from the lawn with a mix of shrubs and woody plants. A lawn right down to the water is the worst thing for the water and it will serve to attract nuisance geese. It's a known fact that keeping the vegetation high at the water's edge will discourage geese from coming onto a property. It also provides many water quality and wildlife (aquatic and near shore) related benefits.
- **Test first, apply later-** It is most important to test your soil before even thinking about applying fertilizers. Once a lawn is established, fertilizing more than once a year (unless the yearly dosage is applied in fractions) is generally excessive and can lead to excess nitrogen loading to surface and groundwater. Lawns tend to need more basic soils so sometimes even applying crushed limestone to raise the pH can release enough nutrients that were bound to the soil to maintain the lawn. A soil test will let you know exactly what you need to maintain a healthy lawn. If the test informs you that only nitrogen is needed, look for low to no phosphorus fertilizer blends (middle number of the N-P-K rating on the bag is zero) as phosphorous causes algae blooms in lakes and ponds. Generally, a well established lawn can survive adequately with no more than 1 to 2 pounds of nitrogen per 1000 square feet. The best time to apply fertilizer on an established lawn is around mid September when the grass is still active enough to incorporate the fertilizer into the plants, the summer draught is over and the surrounding vegetation is well established to capture any runoff from your lawn. Choose slow release fertilizers only, to insure less polluted runoff. Many residents apply crushed limestone in the spring and fertilize in the fall. Some residents have never felt the need to fertilize and others have had their best results just using lake water (which usually contains small amounts of N and low P) for irrigation. It is really up to you to balance the results you are looking for with the minimum applications needed. Remember the NH Comprehensive Shoreline Protection Act prohibits applying anything except limestone in areas within 25 feet of the high water line except in some circumstances like initially establishing a ground cover.
- **Read the fine print!** - A recent survey in Maine indicated that many consumers did not realize that "Weed & Feed" products contain both fertilizers and pesticides. Why pay for and put down something that can potentially threaten the health of pets, children and water quality when you may not need it in the first

place? If you do have weed or insect problems consult with your county Extension educator, landscaper or garden center expert to learn of safer alternative controls. No matter what you choose always read the application directions and never over apply. Many of the plants and animals that form the foundation of the aquatic food web are extremely sensitive to pesticides so your impacts can have serious repercussions. Also be sure to apply only what you need - just because you bought a whole bag does not mean you have to apply all of it. Over-fertilization will cause more pest problems and will threaten surface and ground water supplies.

- **Conserve every drop-** If you are on a public water supply it is best to choose grass species with low watering requirements or use alternative irrigation supplies like rain barrels, cisterns or even the water directly from the shore. Summer water demand for lawns can be very significant in many communities. Depending on the species and soil conditions you should water, only when needed, no more than a half inch to an inch total weekly. You can use a rain gauge or a can to measure rainfall and irrigation amounts. Early morning watering is preferable to minimize evaporation loss but give the water enough time to infiltrate and to allow the leaf blades to completely dry before night so as not to encourage disease problems. Keeping the lawn height at least 3 inches or higher will also encourage deeper roots which require less water (and a mulching mower blade will allow for those grass clippings to recycle nutrients back into the soil). Remember that in times of draught and hot summer lawns are supposed to go dormant. Letting this happen is the most environmentally friendly thing you can do.

So, the choices are yours, you can have a lawn on your property with minimum impact to our waters if you can restrict its size, locate it properly, provide adequate vegetative buffer areas down-slope and use low input design and maintenance methods. To learn more about how informed landscaping can actually improve the water coming off of your property refer to "Landscaping at the Water's Edge: An ecological approach" and/or request a presentation from your Cooperative Extension county Master Gardeners. Jeff Schloss can also be contacted to schedule a talk or workshop for your lake association.

DISTRIBUTION

The 2008 Lake Winnepesaukee (Alton) summary report was distributed to the following individuals/entities through a direct United States Postal Services Mailing:

- William & Jean Smith (water quality monitors)
- Richard Jones (water quality monitor)
- Paul Richardson (water quality monitor)
- Beverly & Richard DiVaio (water quality monitors)
- Katherine Cima (water quality monitor)
- Klaus Biemann
- Town of Alton Conservation Commission
- Town of Alton Planning Department
- Gilman Library
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Additional copies of the 2008 annual report are available upon request through:

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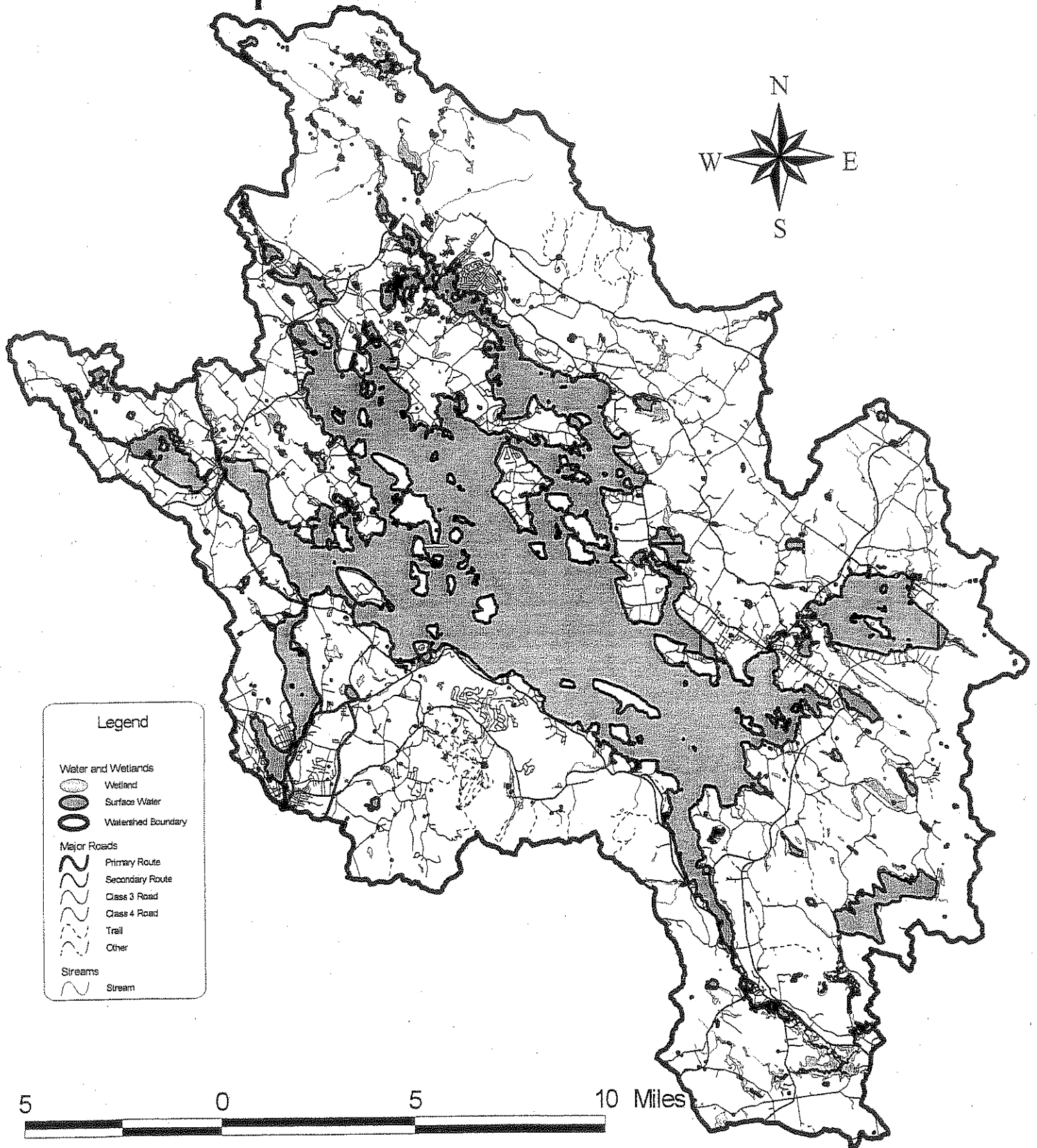
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REPORT FIGURES

Figure 9. Map of the Lake Winnepesaukee Watershed.

Winnepesaukee Watershed

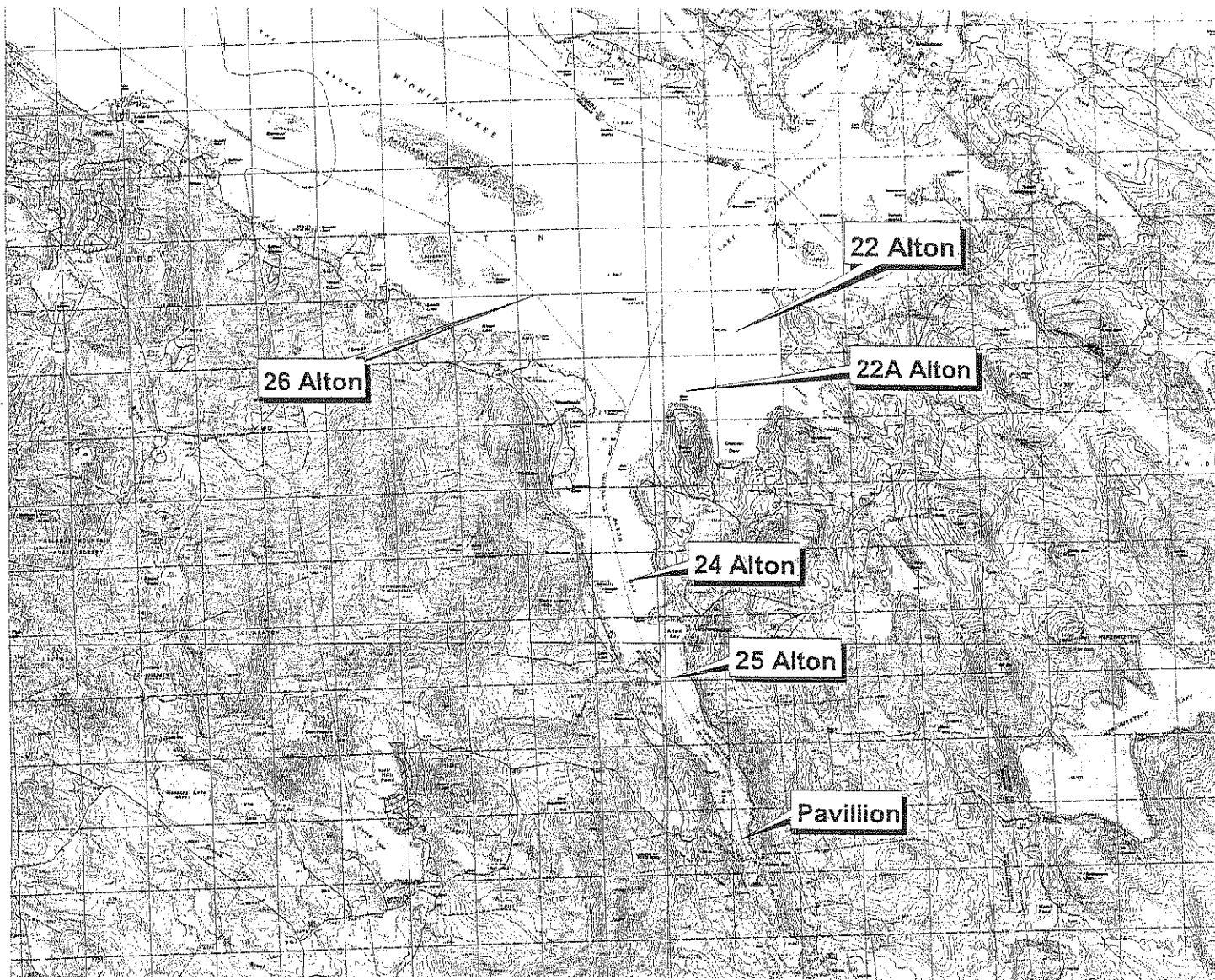


UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

COOPERATIVE EXTENSION

Figure 10. Location of the 2008 Lake Winnepesaukee deep sampling stations: Sites 22A Alton, 24 Alton, 25 Alton, 26 Alton, and the Pavillion, Town of Alton New Hampshire.

Winnepesaukee (Alton) 2008 Sampling Locations



2 0 2 4 Miles

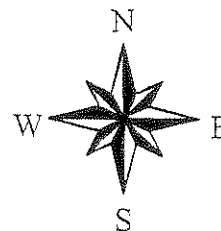
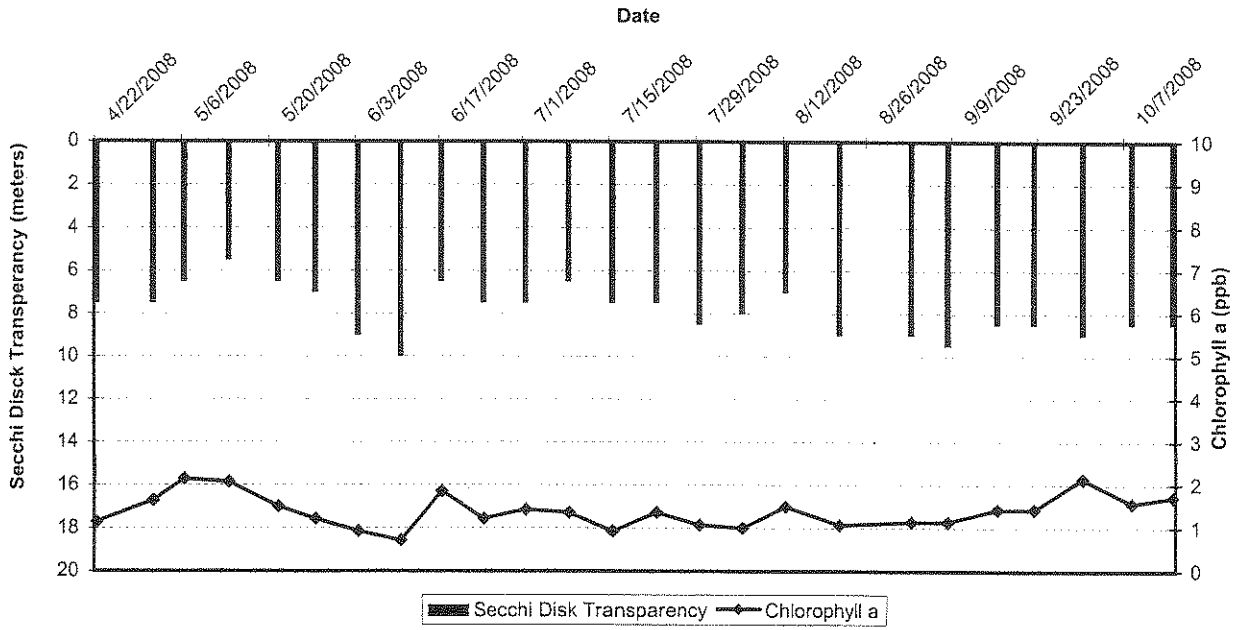


Figure 11. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 22A Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 12. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 22A Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll *a* and dissolved color concentrations often correspond to shallower water transparencies).

Winnepesaukee (Alton - 22A Alton) (2008 Seasonal Data)



Winnepesaukee (Alton) - 22A Alton (2008 Seasonal Data)

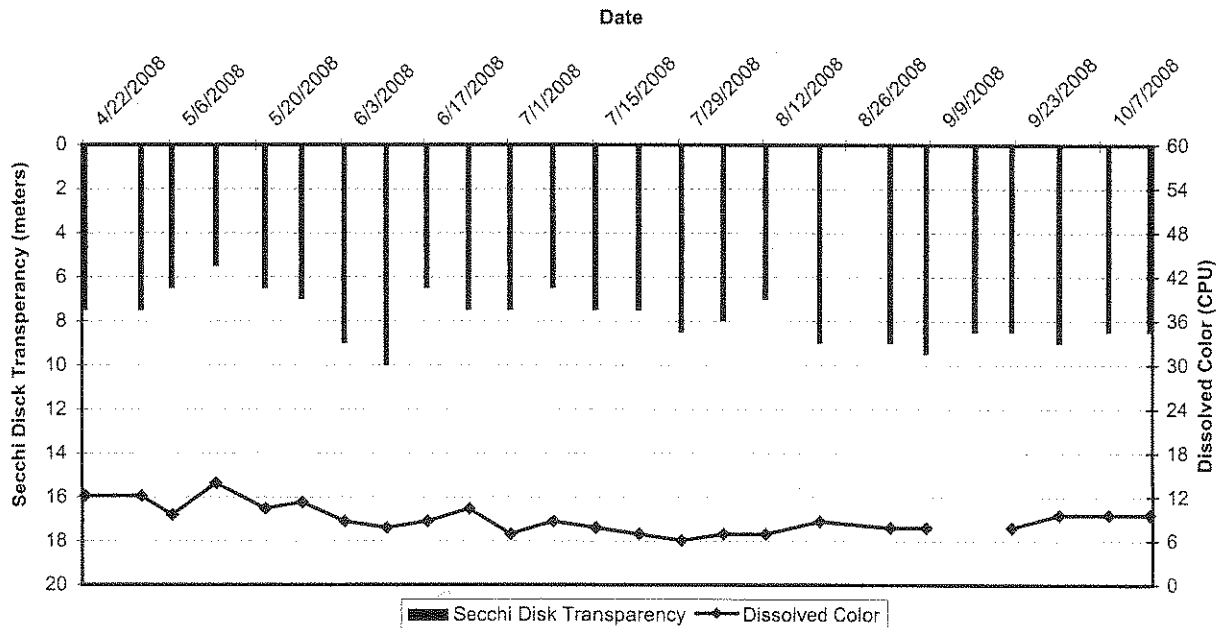
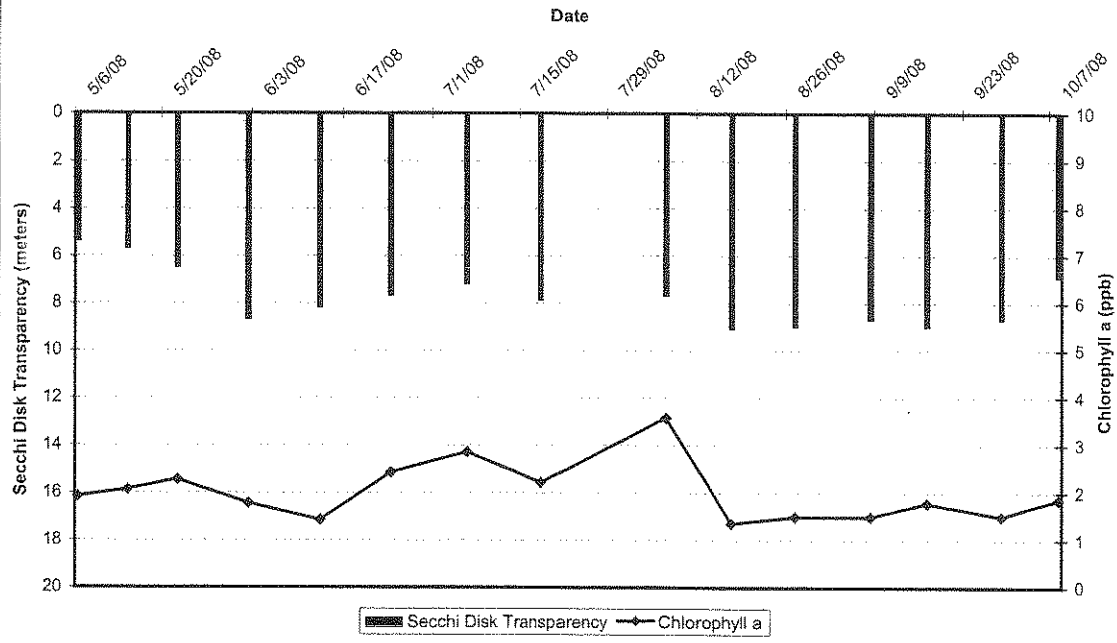


Figure 13. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and chlorophyll a trends for Site 24 Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll a data are reported to the nearest 0.1 parts per billion (ppb).

Figure 14. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 24 Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll a and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll a and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).

Winnepesaukee (Alton) - 24 Alton (2008 Seasonal Data)



Winnepesaukee (Alton) - 24 Alton (2008 Seasonal Data)

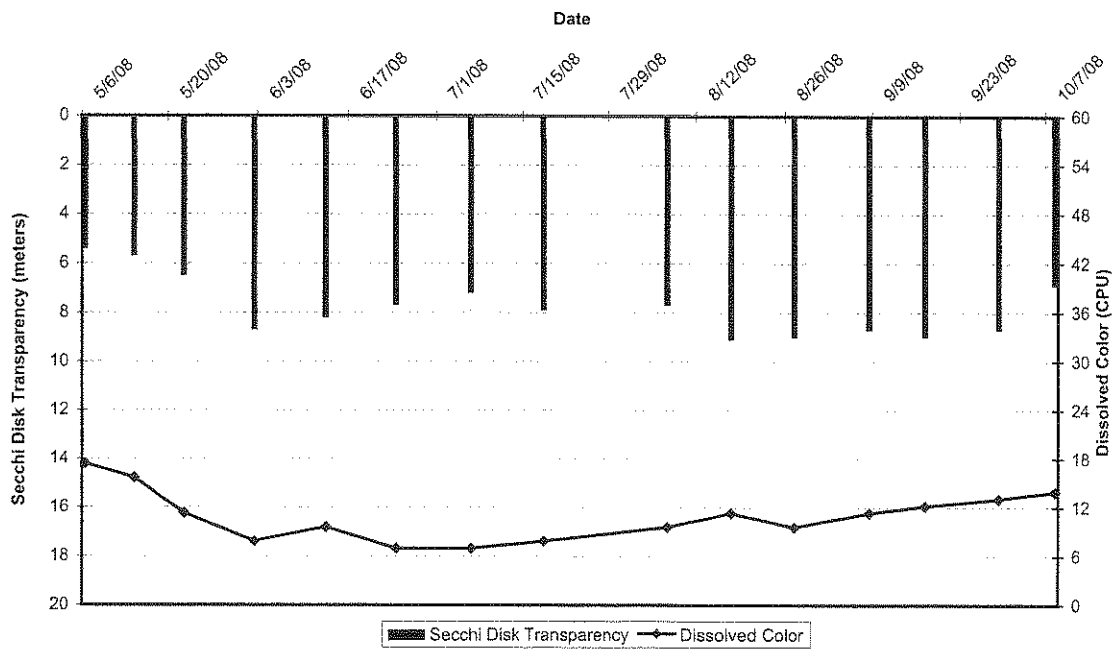
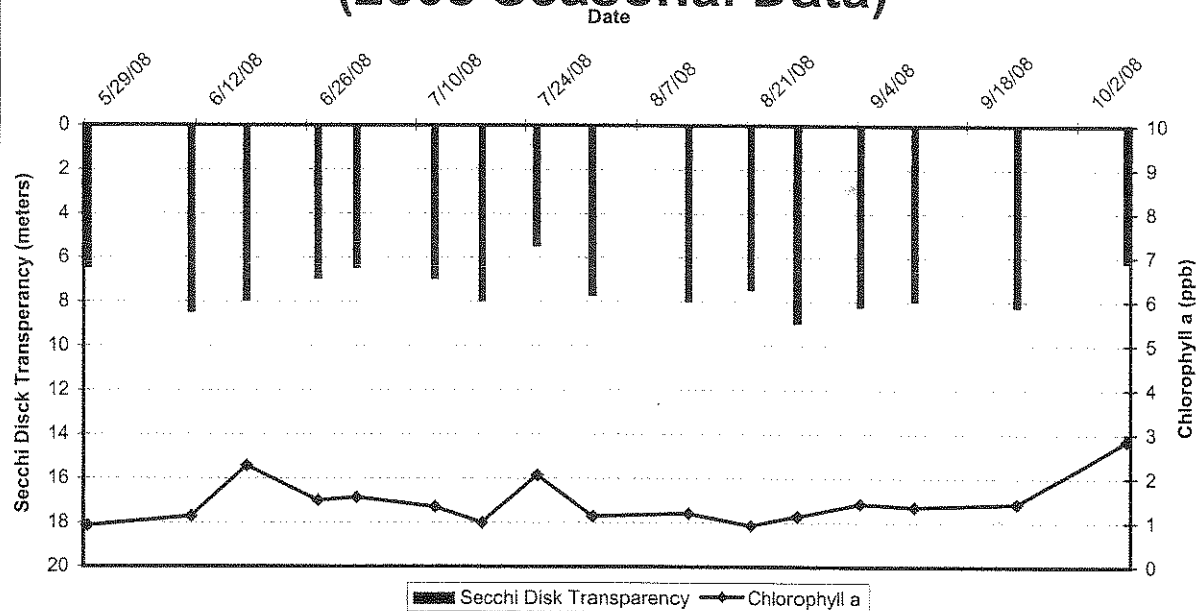


Figure 15. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 25 Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 16. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 25 Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll *a* and dissolved color concentrations often correspond to shallower water transparencies).

Winnepesaukee (Alton) - 25 Alton (2008 Seasonal Data)



Winnepesaukee (Alton) - 25 Alton (2008 Seasonal Data)

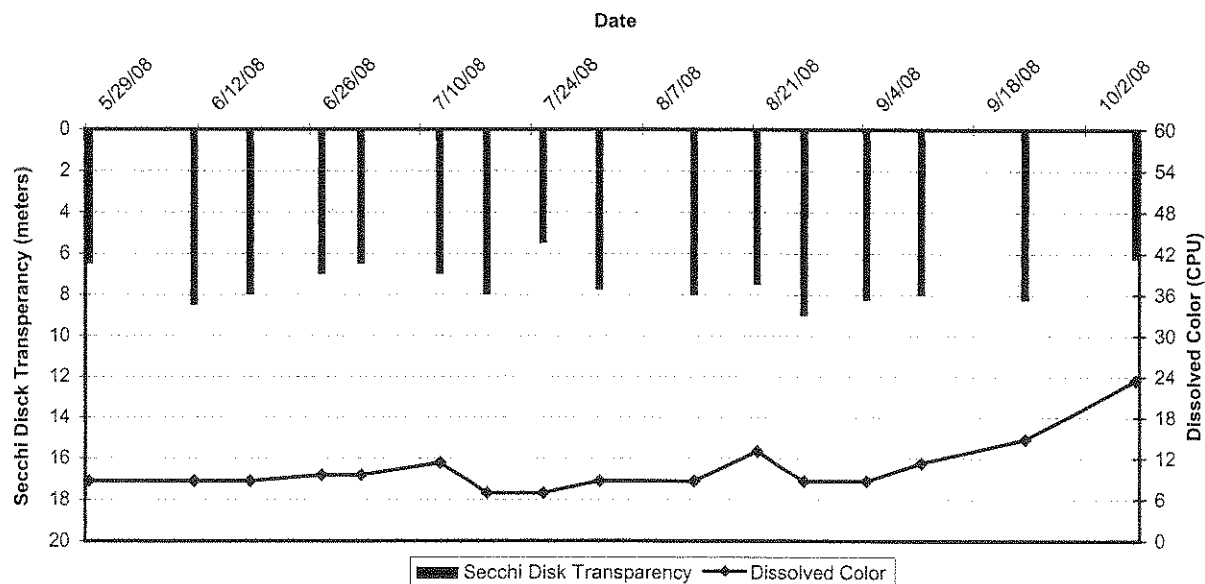
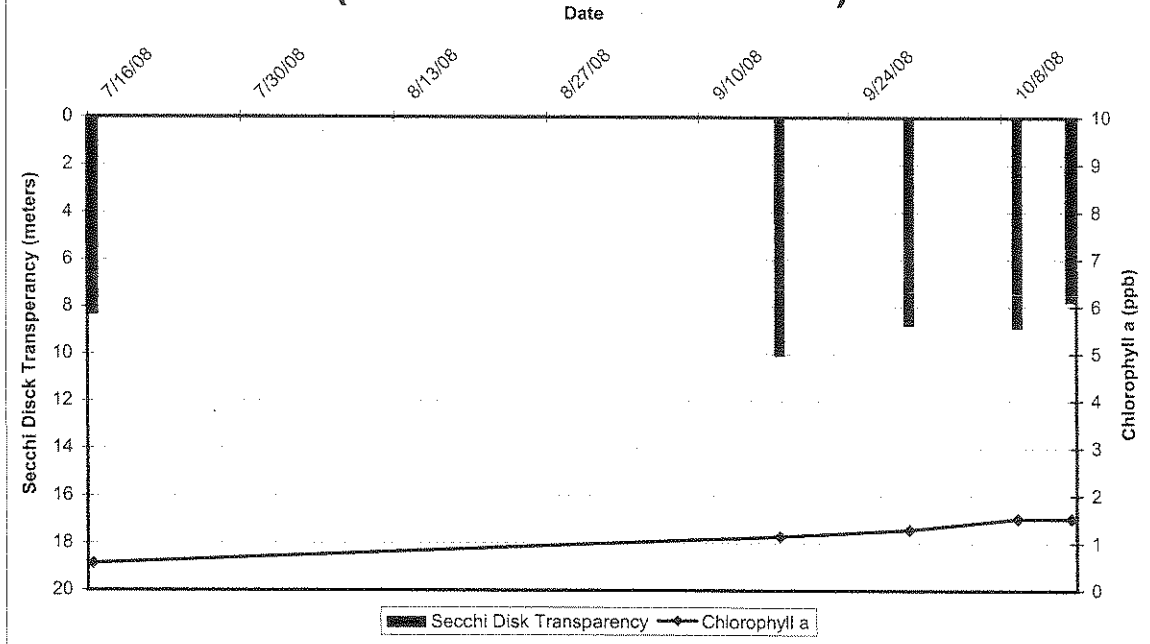


Figure 17. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and chlorophyll a trends for Site 26 Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll a data are reported to the nearest 0.1 parts per billion (ppb).

Figure 18. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 26 Alton. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll a and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll a and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).

Winnepesaukee (Alton) - 26 Alton (2008 Seasonal Data)



Winnepesaukee (Alton) - 26 Alton (2008 Seasonal Data)

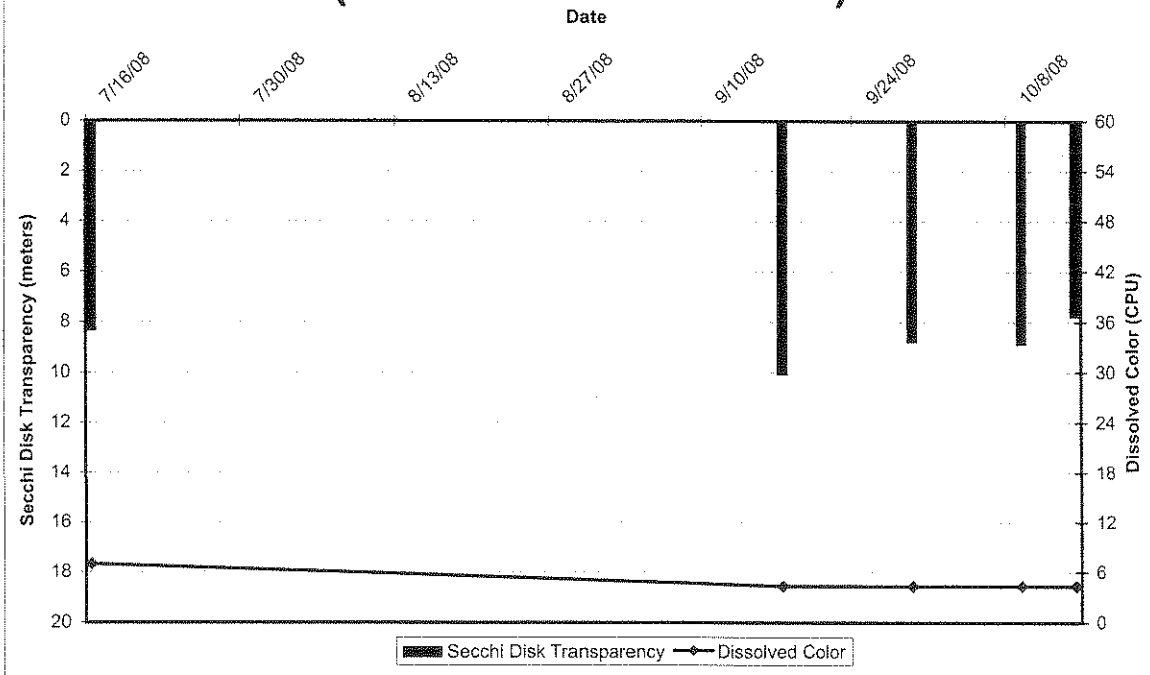
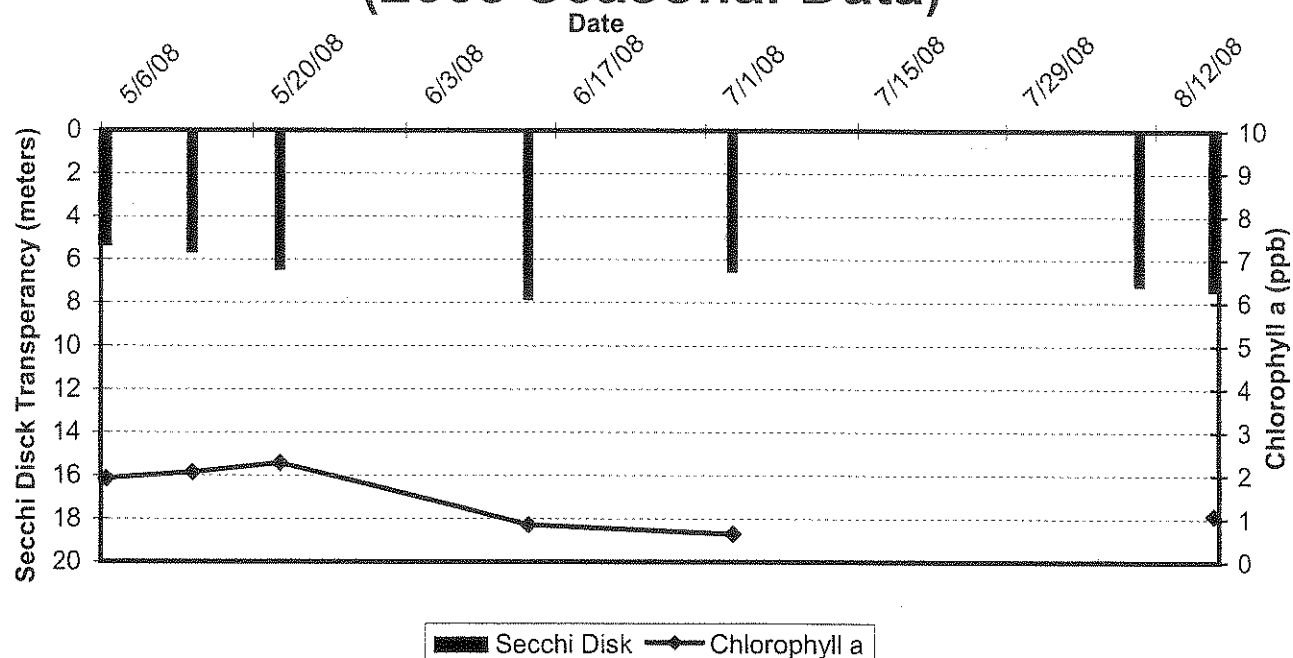


Figure 19. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and chlorophyll a trends for Dellings Cove. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll a data are reported to the nearest 0.1 parts per billion (ppb).

Figure 20. Lake Winnepesaukee -- Alton, 2008. Seasonal Secchi Disk (water transparency) and dissolved color trends for Dellings Cove. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll a and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll a and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).

Winnepesaukee (Alton) - Dellings (2008 Seasonal Data)



Winnepesaukee (Alton) - Dellings (2008 Seasonal Data)

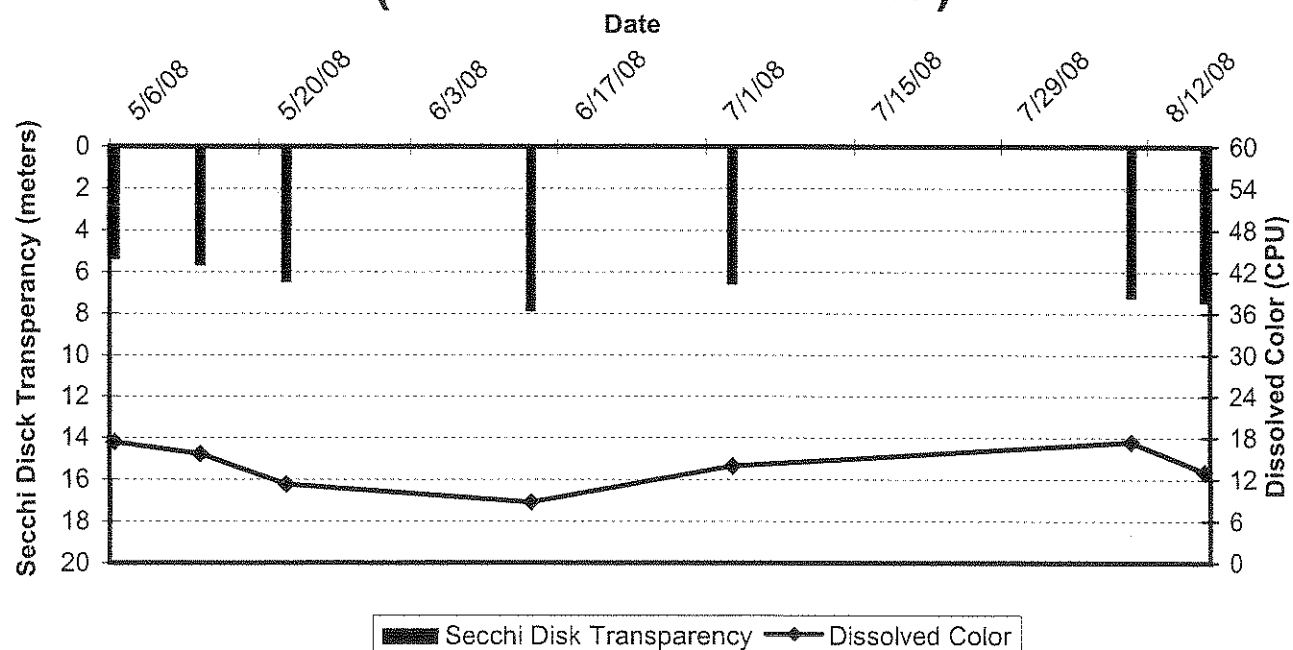
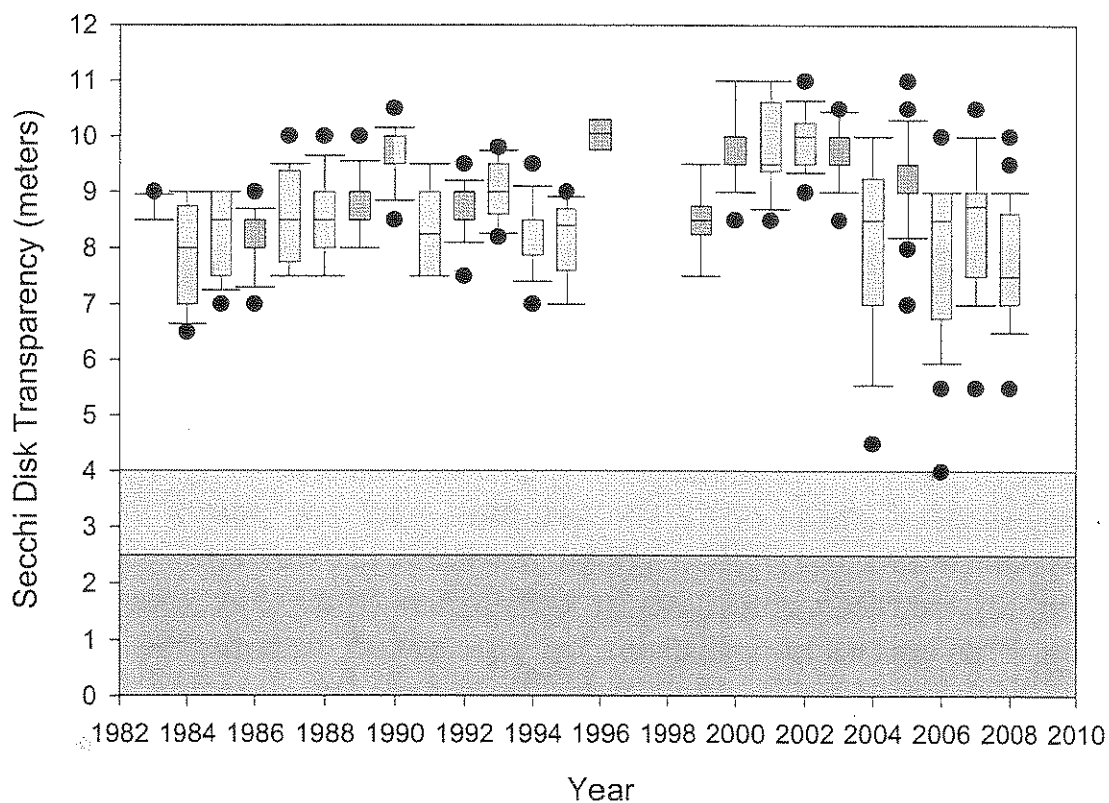


Figure 21. Comparison of the annual Lake Winnepesaukee (Alton), Site 22A Alton, lay monitor Secchi Disk transparency data (2004-2008) that are presented as box and whisker plots. *Note: the historical data collected between 1983 and 2003 were measured at a nearby site (Site 22 Alton) that has historically been characterized by similar water quality.* The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 22. Comparison of the annual Lake Winnepesaukee (Alton), Site 22A Alton, lay monitor chlorophyll a data (2004-2008) that are presented as box and whisker plots. *Note: the historical data collected between 1983 and 2003 were measured at a nearby site (Site 22 Alton) that has historically been characterized by similar water quality.* The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

**Winnepesaukee (Alton) -- Site 22A Alton
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1983-2008**



**Winnepesaukee (Alton) -- Site 22A Alton
Annual Chlorophyll a Comparisons
Box and Whisker Plots: 1983-2008**

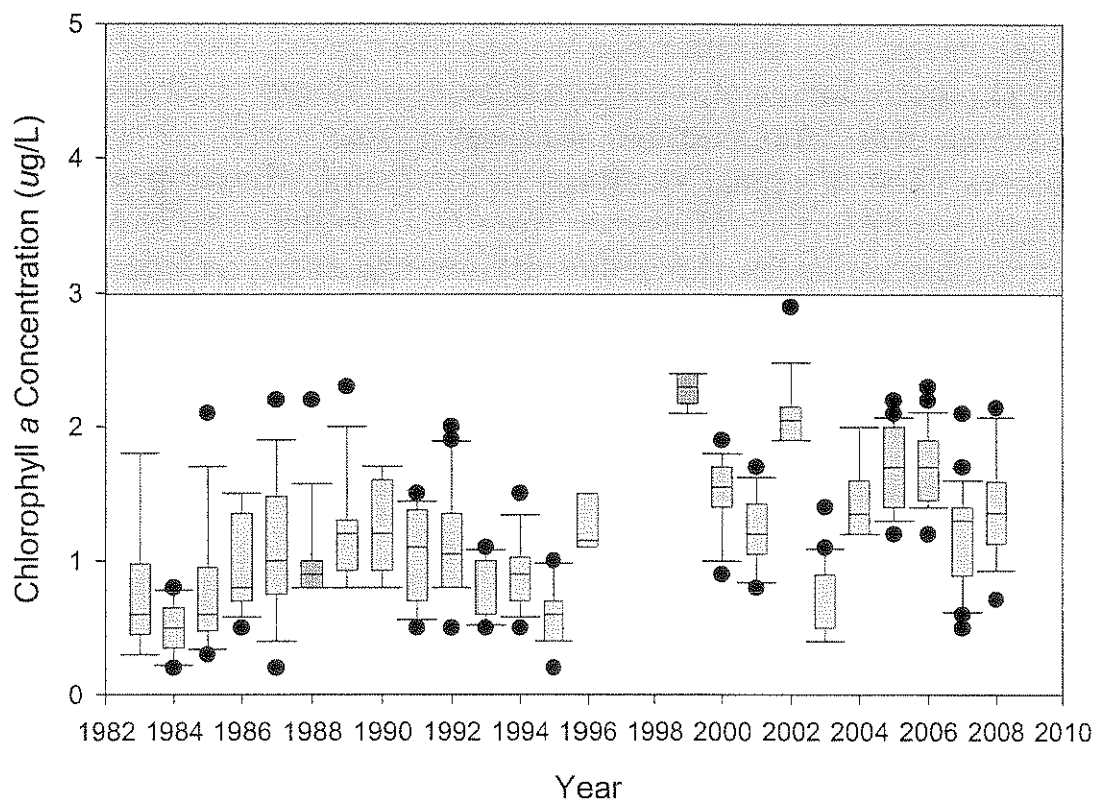
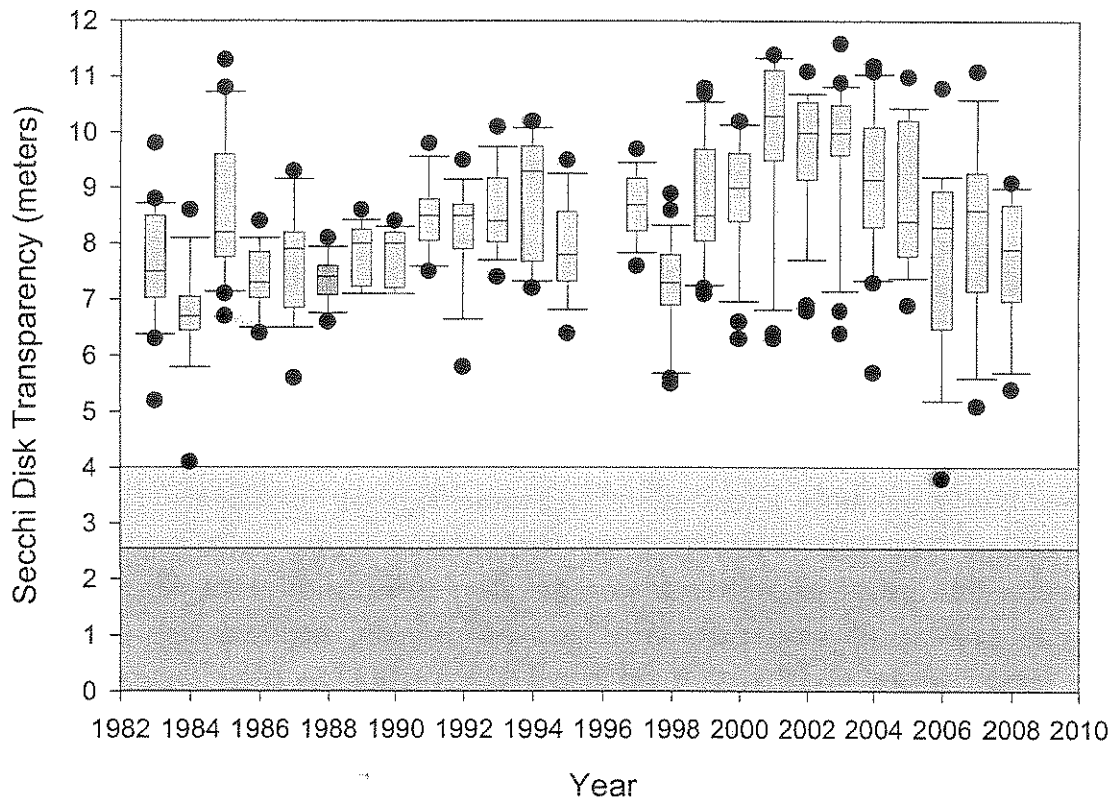


Figure 23. Comparison of the annual Lake Winnepesaukee (Alton), Site 24 Alton, lay monitor Secchi Disk transparency data (1983-2008) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 24. Comparison of the annual Lake Winnepesaukee (Alton), Site 24 Alton, lay monitor chlorophyll α data (1983-2008) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

**Winnepesaukee (Alton) -- Site 24 Alton
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1983-2008**



**Winnepesaukee (Alton) -- Site 24 Alton
Annual Chlorophyll a Comparisons
Box and Whisker Plots: 1983-2008**

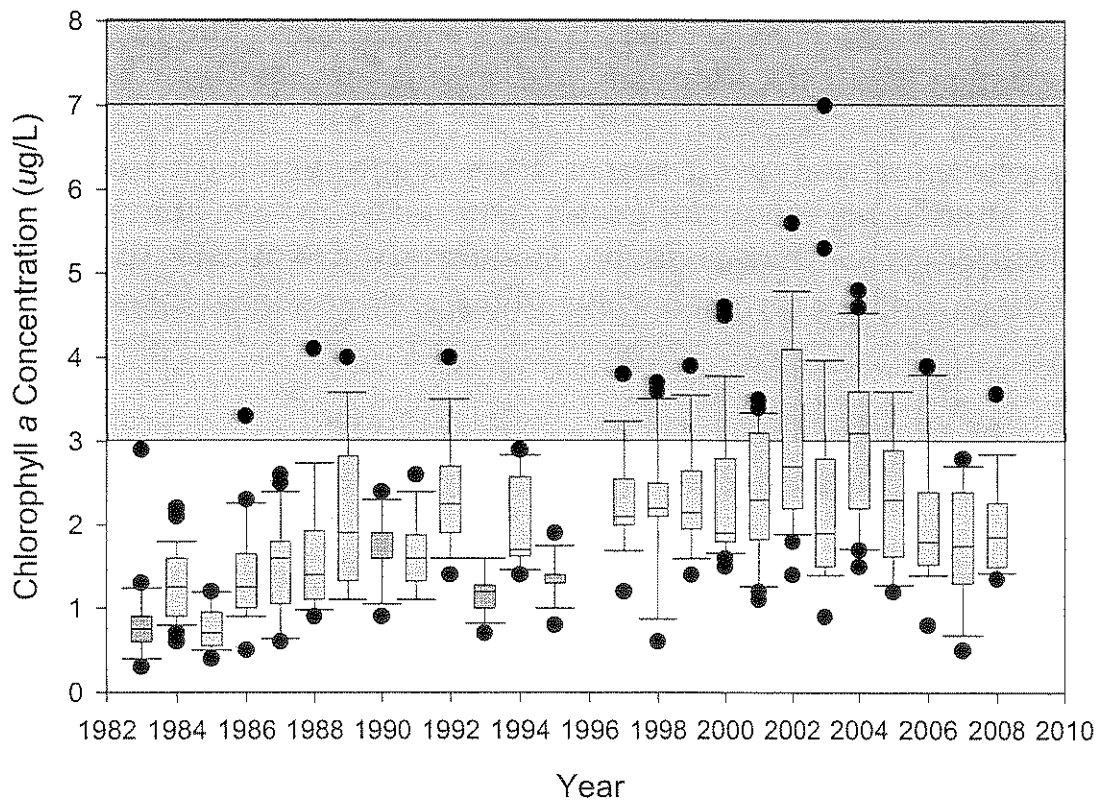
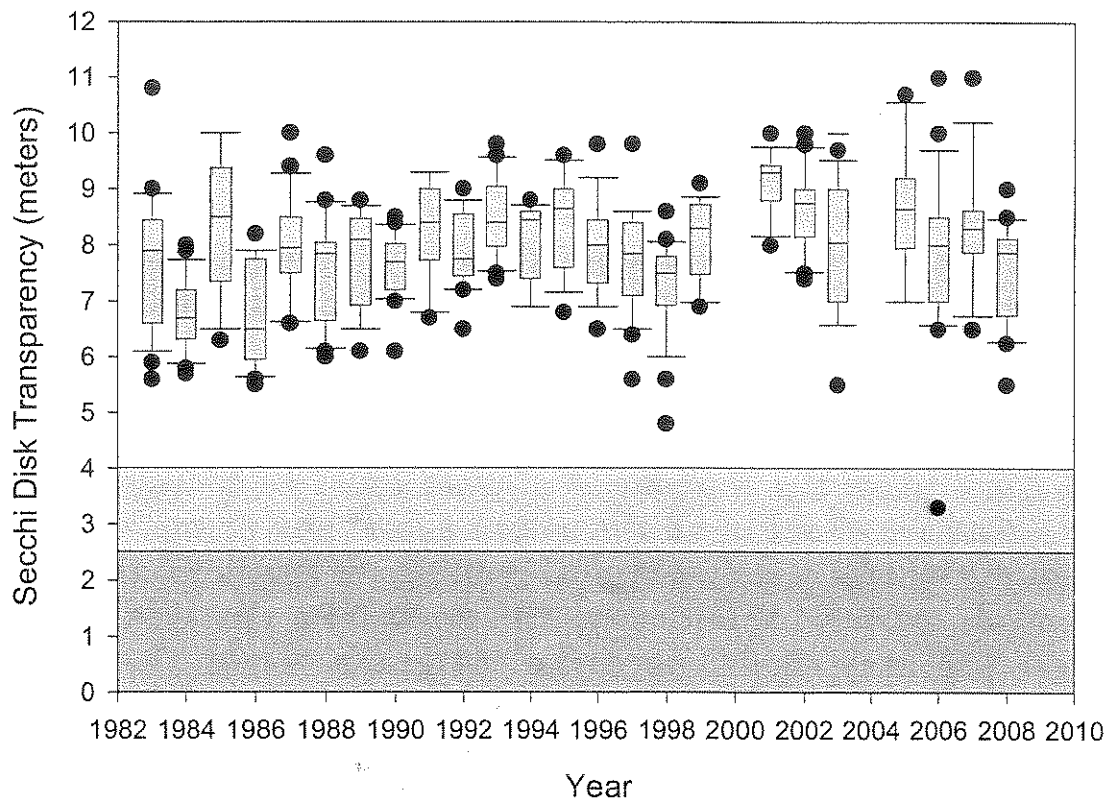


Figure 25. Comparison of the annual Lake Winnepesaukee (Alton), Site 25 Alton, lay monitor Secchi Disk transparency data (1983-2008) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 26. Comparison of the annual Lake Winnepesaukee (Alton), Site 25 Alton, lay monitor chlorophyll *a* data (1983-2008) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

**Winnepesaukee (Alton) -- Site 25 Alton
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1983-2008**



**Winnepesaukee (Alton) -- Site 25 Alton
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1983-2008**

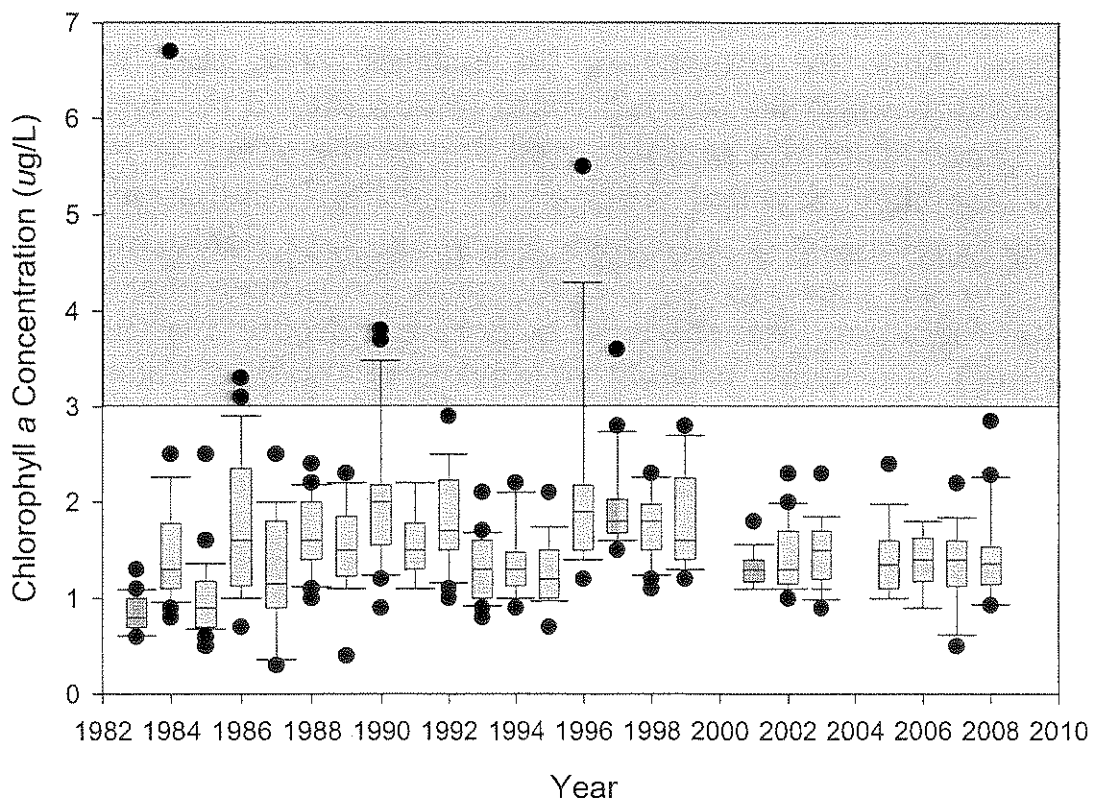
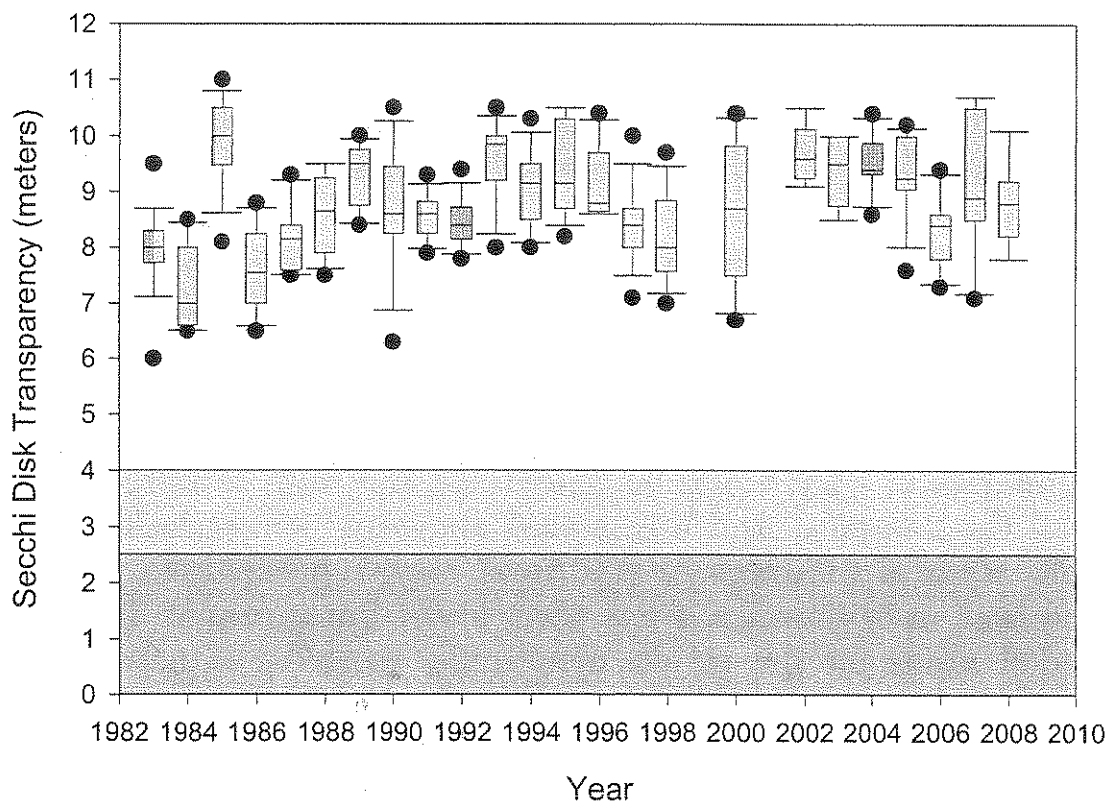


Figure 27. Comparison of the annual Lake Winnepesaukee (Alton), Site 26 Alton, lay monitor Secchi Disk transparency data (1983-2008) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 28. Comparison of the annual Lake Winnepesaukee (Alton), Site 26 Alton, lay monitor chlorophyll a data (1983-2008) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

**Winnepesaukee (Alton) -- Site 26 Alton
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1983-2008**



**Winnepesaukee (Alton) -- Site 26 Alton
Annual Chlorophyll a Comparisons
Box and Whisker Plots: 1983-2008**

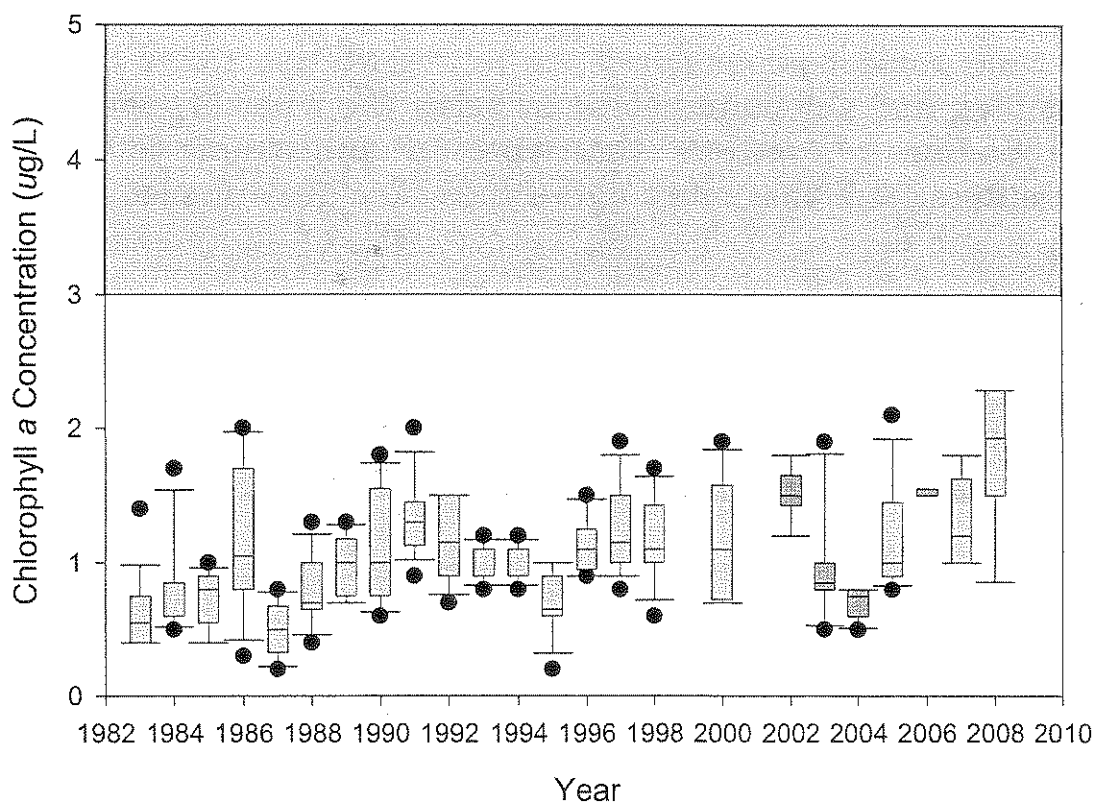
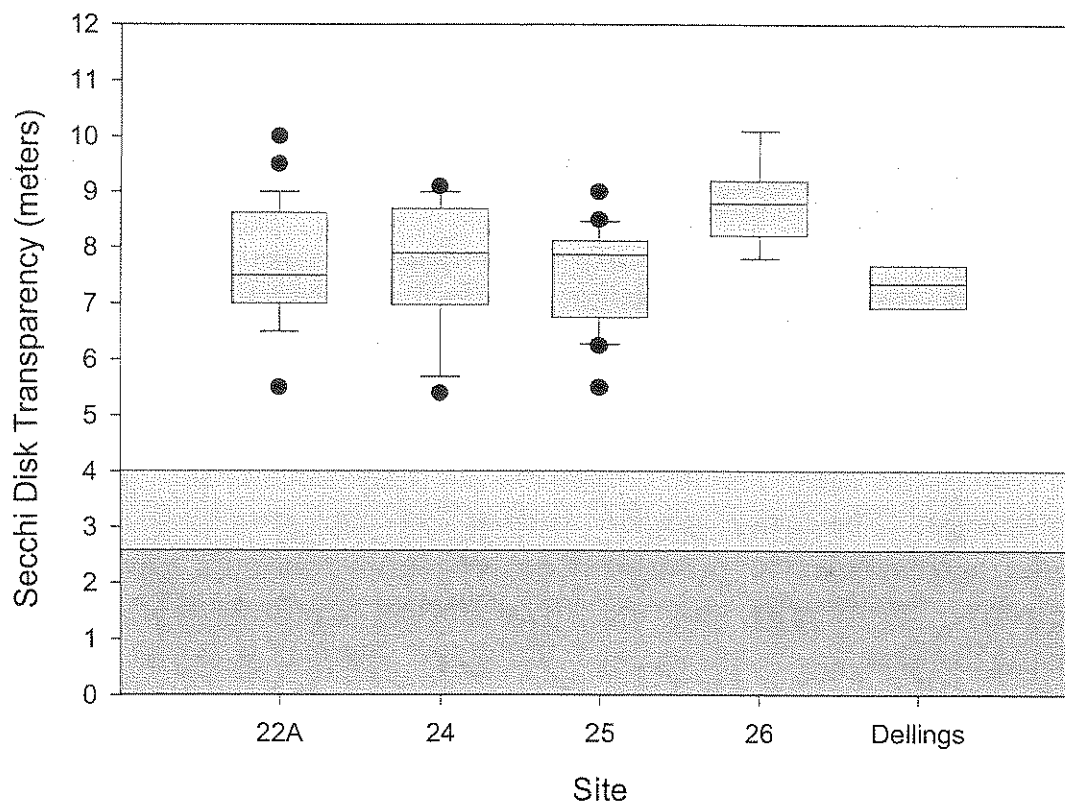


Figure 29. Lake Winnepesaukee (Alton) inter-site comparison of the 2008 lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another site, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that site’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 30. Lake Winnepesaukee (Alton) inter-site comparison of the 2008 lay monitor Chlorophyll a data that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another site, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that site’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

**Winnepesaukee (Alton) -- Inter-Site Comparison
Secchi Disk Transparency Data
Box and Whisker Plots: 2008**



**Winnepesaukee (Alton) -- Inter-Site Comparison
Chlorophyll a Data
Box and Whisker Plots: 2008**

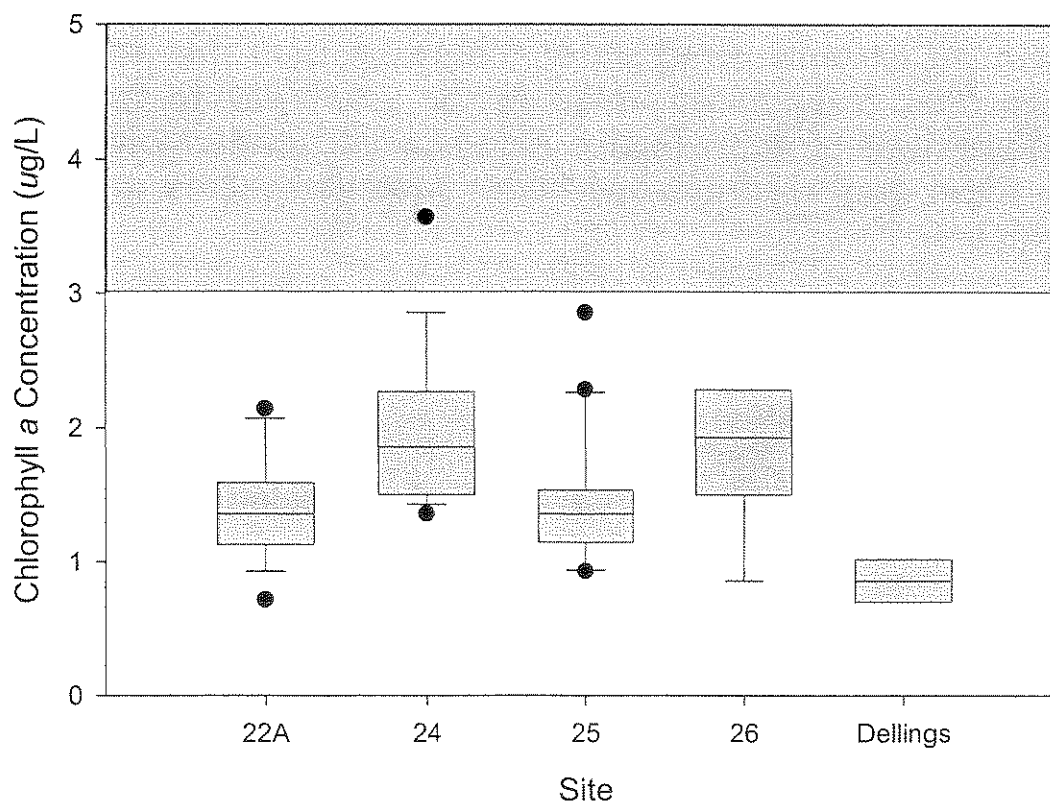


Figure 31. Regional comparison of the 2008 lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another site, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that site’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 32. Regional comparison of the 2008 lay monitor Chlorophyll a data that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another site, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that site’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Key:

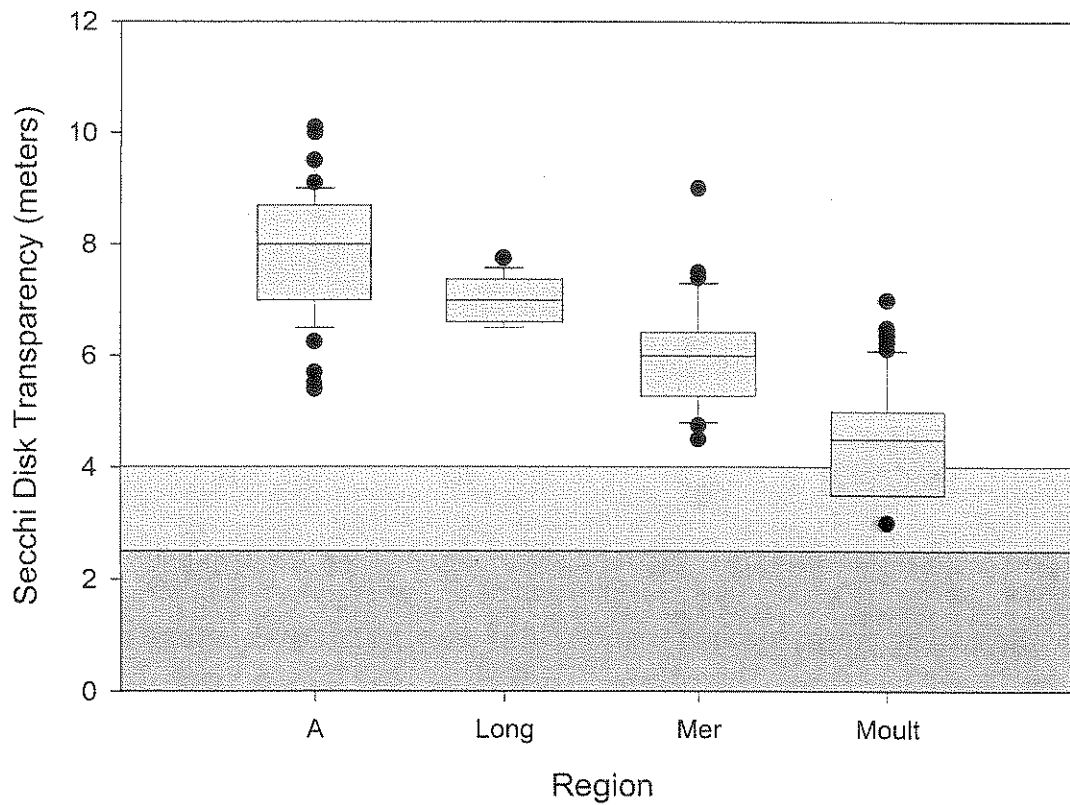
A = Alton

Long = Long Island

Mer = Meredith Bay

Moult = Moultonborough Bay/Tuftenboro region

Winnepesaukee -- Region Comparison
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 2008



Winnepesaukee -- Region Comparison
Annual Chlorophyll a Comparisons
Box and Whisker Plots: 2008

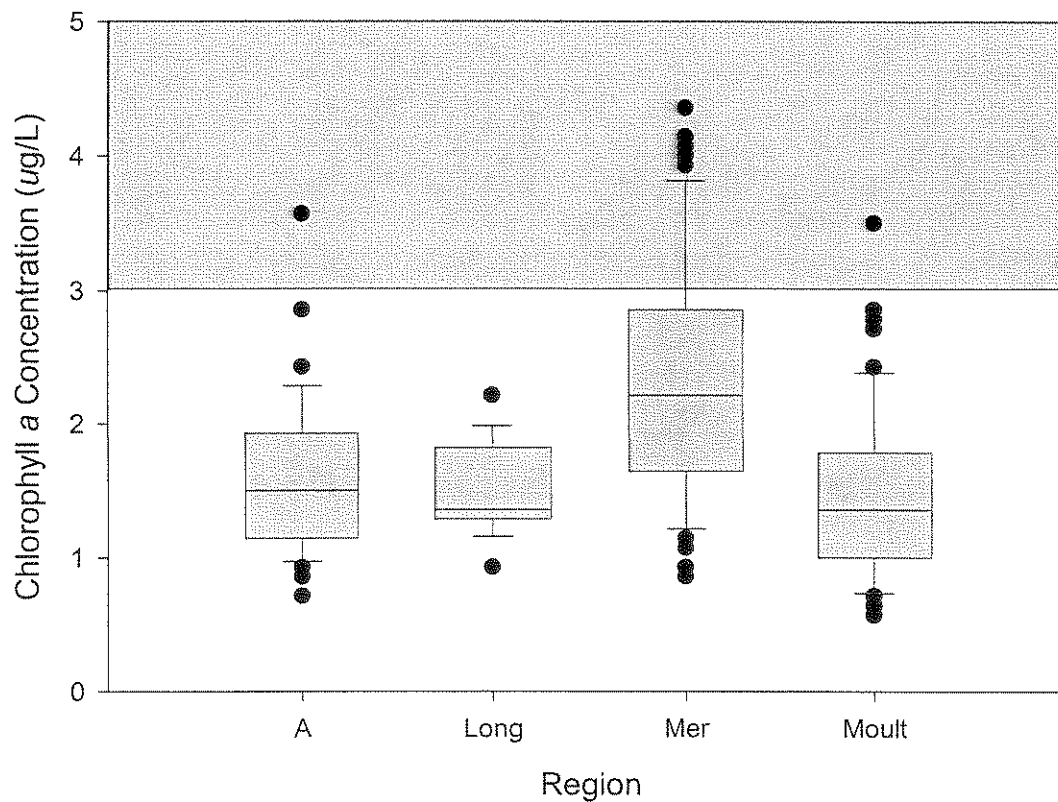
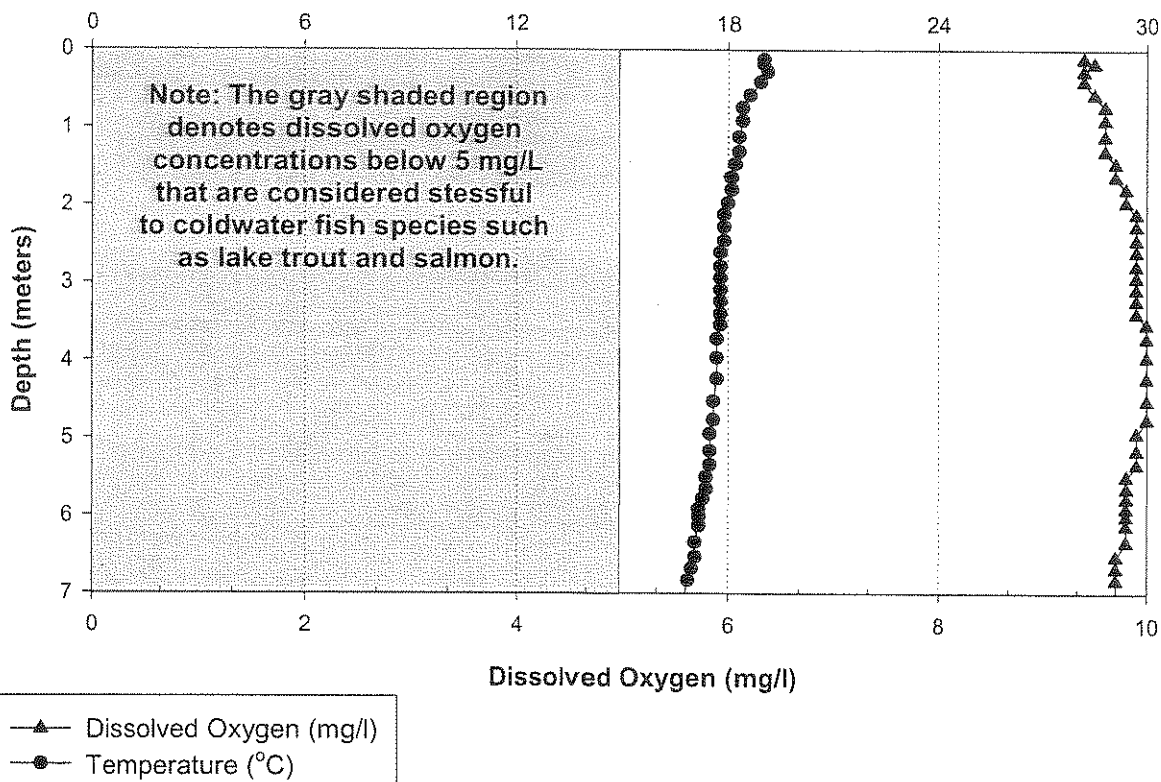


Figure 33. Lake Winnepesaukee (Alton) temperature and dissolved oxygen profiles, the Pavillion and Site 25 Alton, on June 19, 2008. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to coldwater fish. The temperature and dissolved oxygen data were collected at approximately ten centimeter increments and are reported as degrees Celcius (°C) and as parts per million (ppm), respectively.

Winnepesaukee (Alton) - Pavillion

June 19, 2008

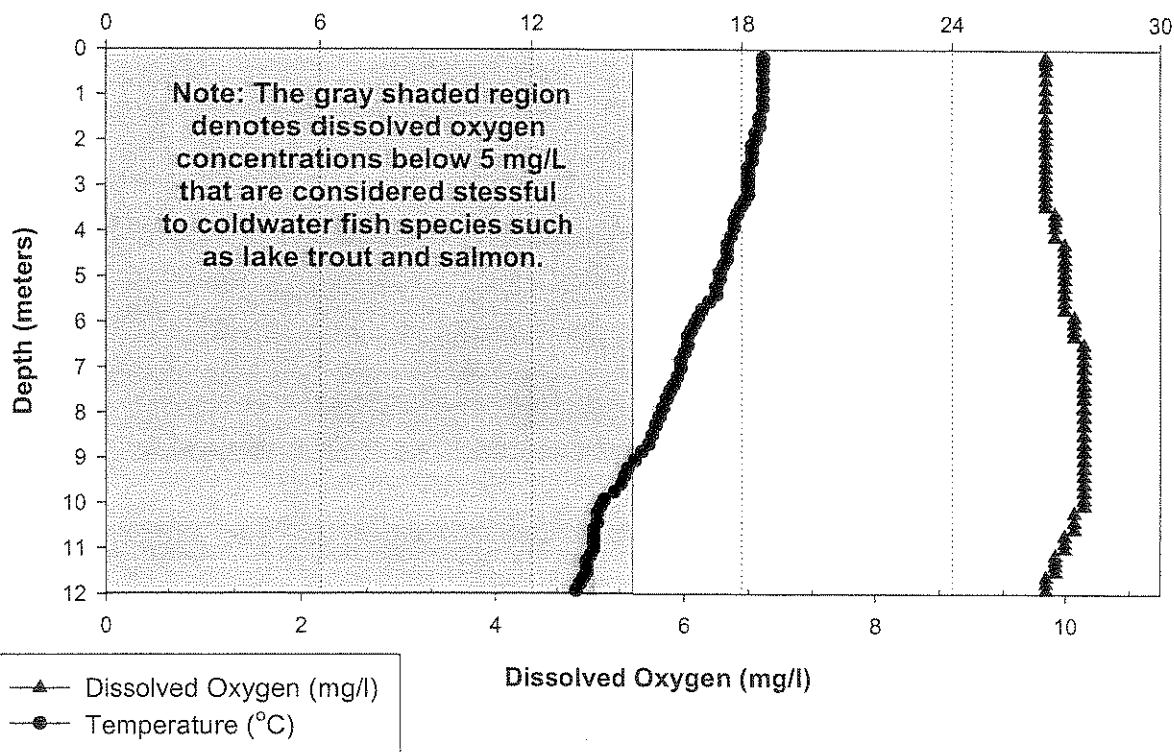
Temperature (°C)



Winnepesaukee (Alton) - Site 25 Alton

June 19, 2008

Temperature (°C)



APPENDIX A

Lakes Lay Monitoring Program, U.N.H. [Lay Monitor Data]

Lake Winnepesaukee, Alton NH

--subset of trophic indicators, all sites, 2008

Average transparency:	7.8 (2008:	65 Values;	5.4 -	10.1 range)
Average chlorophyll:	1.5 (2008:	64 Values;	0.6 -	3.6 range)
Average color:	9.8 (2008:	64 Values;	4.3 -	23.5 range)
Average Alkalinity (gray):	6.7 (2008:	56 Values;	5.4 -	7.4 range)
Average alkalinity (pink):	7.0 (2008:	56 Values;	5.8 -	7.8 range)
Total phosphorus (ug/L):	8.1 (2008:	54 Values;	3.3 -	66.7 range)

Site	Date	Secchi Disk Transparency (meters)	Chl <i>a</i> (ppb)	Dissolved Color (CPU)	Alkalinity gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phos. (ppb)
22A Black Pt	4/22/2008	7.5	1.1	12.2	6.6	6.8	5.0
22A Black Pt	5/1/2008	7.5	1.6	12.2	6.5	6.7	5.6
22A Black Pt	5/6/2008	6.5	2.1	9.6	6.2	6.5	5.4
22A Black Pt	5/13/2008	5.5	2.1	13.9	6.5	6.7	6.4
22A Black Pt	5/21/2008	6.5	1.5	10.4	6.6	6.8	5.4
22A Black Pt	5/27/2008	7.0	1.2	11.3	6.7	6.9	6.1
22A Black Pt	6/3/2008	9.0	0.9	8.7	7.2	7.4	4.7
22A Black Pt	6/10/2008	10.0	0.7	7.8	7.4	7.6	6.6
22A Black Pt	6/17/2008	6.5	1.9	8.7	6.4	6.6	8.4
22A Black Pt	6/24/2008	7.5	1.2	10.4	6.5	6.7	7.2
22A Black Pt	7/1/2008	7.5	1.4	7.0	7.2	7.5	8.1
22A Black Pt	7/8/2008	6.5	1.4	8.7	6.8	7.1	5.7
22A Black Pt	7/15/2008	7.5	0.9	7.8	6.7	7.0	5.4
22A Black Pt	7/22/2008	7.5	1.4	7.0	6.9	7.2	7.0
22A Black Pt	7/29/2008	8.5	1.1	6.1	6.4	6.6	5.1
22A Black Pt	8/5/2008	8.0	1.0	7.0	6.2	6.4	6.5
22A Black Pt	8/12/2008	7.0	1.5	7.0	6.9	7.1	-----
22A Black Pt	8/21/2008	9.0	1.1	8.7	7.2	7.4	-----
22A Black Pt	9/2/2008	9.0	1.1	7.8	6.7	6.9	4.6
22A Black Pt	9/8/2008	9.5	1.1	7.8	7.0	7.2	5.4
22A Black Pt	9/16/2008	8.5	1.4	-----	6.8	7.0	4.6
22A Black Pt	9/22/2008	8.5	1.4	7.8	7.1	7.3	5.0
22A Black Pt	9/30/2008	9.0	2.1	9.6	7.0	7.2	4.5
22A Black Pt	10/8/2008	8.5	1.6	9.6	7.1	7.3	5.6
22A Black Pt	10/15/2008	8.5	1.7	9.6	7.0	7.2	4.5
24 Alton	5/6/2008	5.4	1.9	17.4	5.4	5.8	11.3

Site	Date	Secchi Disk Transparency (meters)	Chl <i>a</i> (ppb)	Dissolved Color (CPU)	Alkalinity gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phos. (ppb)
24 Alton	5/14/2008	5.7	2.1	15.6	6.0	6.5	9.9
24 Alton	5/22/2008	6.5	2.3	11.3	6.3	6.7	14.2
24 Alton	6/2/2008	8.7	1.8	7.8	6.1	6.6	6.1
24 Alton	6/13/2008	8.2	1.4	9.6	5.9	6.4	66.7
24 Alton	6/24/2008	7.7	2.4	7.0	6.5	6.9	7.3
24 Alton	7/6/2008	7.2	2.9	7.0	6.8	7.2	8.1
24 Alton	7/18/2008	7.9	2.2	7.8	6.3	6.8	15.1
24 Alton	8/7/2008	7.7	3.6	9.6	6.4	6.8	12.1
24 Alton	8/17/2008	9.1	1.4	11.3	6.1	6.5	11.7
24 Alton	8/27/2008	9.0	1.5	9.6	6.2	6.6	9.7
24 Alton	9/8/2008	8.7	1.5	11.3	5.9	6.4	7.2
24 Alton	9/17/2008	9.0	1.8	12.2	6.0	6.5	8.7
24 Alton	9/29/2008	8.7	1.5	13.0	6.4	6.8	8.3
24 Alton	10/8/2008	6.9	1.9	13.9	6.3	6.8	9.2
25 Alton	5/29/2008	6.5	0.8	8.7	7.4	7.7	8.4
25 Alton	6/11/2008	8.5	1.0	8.7	7.2	7.8	5.2
25 Alton	6/18/2008	8.0	2.0	8.7	7.2	7.5	7.7
25 Alton	6/27/2008	7.0	1.3	9.6	7.2	7.5	5.1
25 Alton	7/2/2008	6.5	1.4	9.6	7.3	7.6	4.4
25 Alton	7/12/2008	7.0	1.2	11.3	7.4	7.7	4.9
25 Alton	7/18/2008	8.0	0.9	7.0	7.0	7.4	3.3
25 Alton	7/25/2008	5.5	1.8	7.0	7.3	7.7	6.3
25 Alton	8/1/2008	7.8	1.0	8.7	6.8	7.1	4.4
25 Alton	8/13/2008	8.0	1.1	8.7	7.0	7.2	5.2
25 Alton	8/21/2008	7.5	0.8	13.0	7.1	7.4	7.4
25 Alton	8/27/2008	9.0	1.0	8.7	7.0	7.4	7.1
25 Alton	9/4/2008	8.3	1.3	8.7	7.1	7.5	4.7
25 Alton	9/11/2008	8.0	1.2	11.3	6.7	7.0	5.7
25 Alton	9/24/2008	8.3	1.3	14.8	7.0	7.3	10.5
25 Alton	10/8/2008	6.3	2.6	23.5	6.9	7.3	6.2
26 Alton	7/16/2008	8.4	0.6	7.0	-----	-----	-----
26 Alton	9/17/2008	10.1	1.1	4.3	-----	-----	-----
26 Alton	9/29/2008	8.8	1.3	4.3	-----	-----	-----
26 Alton	10/9/2008	8.9	1.5	4.3	-----	-----	-----
26 Alton	10/14/2008	7.8	1.5	4.3	-----	-----	-----
Dellings	6/14/2008	7.9	0.9	8.7	-----	-----	-----
Dellings	7/3/2008	6.6	0.6	13.9	-----	-----	-----
Dellings	8/10/2008	7.3	-----	17.4	-----	-----	-----
Dellings	8/17/2008	7.5	1.1	13.0	-----	-----	-----

<< end of 2008 data listing; 65 records >>

**Lakes Lay Monitoring Program, U.N.H.
[2008 Center for Freshwater Biology Data]**

Site	Date	Depth (meters)	Carbon Dioxide (mg/L)	Alkalinity gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt @ pH 4.6 (mg/L)	Total Phosphorus (ug/L)	Chlorophyll <i>a</i> (ug/L)	Dissolved Color (CPU)
25 Alton	6/19/2008	0.5	1.0	7.8	8.7	-----	2.2	12.2
25 Alton	6/19/2008	7.5	1.5	7.9	9.0	6.9	1.5	7.8
25 Alton	6/19/2008	12.8	3.6	-----	-----	8.4	2.1	8.7
25 Alton	6/19/2008	0-5.5	-----	8.2	9.2	6.4	-----	-----
Pavillion	6/19/2008	0.5	-----	8.6	9.7	12.1	1.8	9.6
Pavillion	6/19/2008	3.0	0.9	-----	-----	-----	1.3	23.5
Pavillion	6/19/2008	6.5	1.2	7.1	8.1	7.2	-----	-----
Pavillion	6/19/2008	0-6.5	-----	8.1	9.0	9.3	1.4	10.4

Site	Date	Secchi Disk Transparency (meters)
25 Alton	6/19/08	7.1 meters
Pavillion	6/19/08	6.5 meters

Site	Date	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat.)	Specific Conductivity @ 25°C (uS/cm)
25 Alton	6/19/2008	0.18	18.6	9.8	104.7	64.0
25 Alton	6/19/2008	0.22	18.6	9.8	104.7	64.0
25 Alton	6/19/2008	0.32	18.6	9.8	104.7	64.0
25 Alton	6/19/2008	0.47	18.6	9.8	104.5	64.0
25 Alton	6/19/2008	0.67	18.6	9.8	104.5	64.0
25 Alton	6/19/2008	0.88	18.6	9.8	104.4	64.0
25 Alton	6/19/2008	1.08	18.6	9.8	104.3	64.0
25 Alton	6/19/2008	1.27	18.6	9.8	104.2	64.0
25 Alton	6/19/2008	1.50	18.5	9.8	104.1	64.0
25 Alton	6/19/2008	1.69	18.5	9.8	104.1	64.0
25 Alton	6/19/2008	1.85	18.4	9.8	104.2	64.0
25 Alton	6/19/2008	1.98	18.4	9.8	104.3	64.0
25 Alton	6/19/2008	2.12	18.3	9.8	104.1	64.0
25 Alton	6/19/2008	2.28	18.3	9.8	104.0	64.0
25 Alton	6/19/2008	2.45	18.3	9.8	104.3	64.0
25 Alton	6/19/2008	2.60	18.2	9.8	104.3	64.0
25 Alton	6/19/2008	2.75	18.2	9.8	104.2	64.0
25 Alton	6/19/2008	2.90	18.2	9.8	104.1	64.0
25 Alton	6/19/2008	3.03	18.2	9.8	104.1	64.0
25 Alton	6/19/2008	3.20	18.2	9.8	104.0	64.0
25 Alton	6/19/2008	3.34	18.1	9.8	104.1	64.0
25 Alton	6/19/2008	3.46	18.0	9.8	104.0	64.0
25 Alton	6/19/2008	3.62	17.9	9.9	104.2	64.0
25 Alton	6/19/2008	3.76	17.8	9.9	104.4	64.0

Site	Date	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat.)	Specific Conductivity @ 25°C (uS/cm)
25 Alton	6/19/2008	3.92	17.8	9.9	104.4	64.0
25 Alton	6/19/2008	4.13	17.7	9.9	104.4	64.0
25 Alton	6/19/2008	4.30	17.6	10.0	104.5	64.0
25 Alton	6/19/2008	4.45	17.6	10.0	104.5	64.0
25 Alton	6/19/2008	4.62	17.6	10.0	104.5	64.0
25 Alton	6/19/2008	4.75	17.5	10.0	104.4	64.0
25 Alton	6/19/2008	4.91	17.4	10.0	104.2	64.0
25 Alton	6/19/2008	5.06	17.4	10.0	104.0	64.0
25 Alton	6/19/2008	5.23	17.3	10.0	103.8	64.0
25 Alton	6/19/2008	5.40	17.3	10.0	103.6	64.0
25 Alton	6/19/2008	5.56	17.1	10.0	103.6	64.0
25 Alton	6/19/2008	5.74	16.9	10.0	103.5	64.0
25 Alton	6/19/2008	5.89	16.8	10.1	103.7	64.0
25 Alton	6/19/2008	6.04	16.7	10.1	103.7	64.0
25 Alton	6/19/2008	6.19	16.6	10.1	103.8	64.0
25 Alton	6/19/2008	6.32	16.5	10.1	103.8	64.0
25 Alton	6/19/2008	6.51	16.5	10.2	103.9	64.0
25 Alton	6/19/2008	6.68	16.4	10.2	104.0	64.0
25 Alton	6/19/2008	6.85	16.3	10.2	103.8	64.0
25 Alton	6/19/2008	7.02	16.3	10.2	103.7	64.0
25 Alton	6/19/2008	7.21	16.2	10.2	103.5	64.0
25 Alton	6/19/2008	7.38	16.1	10.2	103.2	64.0
25 Alton	6/19/2008	7.52	16.0	10.2	103.2	64.0
25 Alton	6/19/2008	7.69	15.9	10.2	103.2	64.0
25 Alton	6/19/2008	7.90	15.8	10.2	103.0	64.0
25 Alton	6/19/2008	8.09	15.7	10.2	102.5	64.0
25 Alton	6/19/2008	8.28	15.6	10.2	102.4	64.0
25 Alton	6/19/2008	8.50	15.5	10.2	102.1	64.0
25 Alton	6/19/2008	8.70	15.4	10.2	101.7	64.0
25 Alton	6/19/2008	8.87	15.2	10.2	101.5	64.0
25 Alton	6/19/2008	9.06	15.0	10.2	101.4	64.0
25 Alton	6/19/2008	9.24	14.8	10.2	100.9	64.0
25 Alton	6/19/2008	9.41	14.7	10.2	100.6	64.0
25 Alton	6/19/2008	9.59	14.6	10.2	100.2	64.0
25 Alton	6/19/2008	9.76	14.4	10.2	99.6	64.0
25 Alton	6/19/2008	9.93	14.1	10.2	99.2	64.0
25 Alton	6/19/2008	10.07	14.0	10.2	98.7	64.0
25 Alton	6/19/2008	10.23	13.9	10.1	98.2	64.0
25 Alton	6/19/2008	10.43	13.9	10.1	97.8	64.0
25 Alton	6/19/2008	10.59	13.8	10.1	97.3	64.0
25 Alton	6/19/2008	10.74	13.8	10.0	96.9	64.0
25 Alton	6/19/2008	10.89	13.8	10.0	96.4	64.0
25 Alton	6/19/2008	11.02	13.8	10.0	96.2	64.0
25 Alton	6/19/2008	11.17	13.7	9.9	95.9	64.0
25 Alton	6/19/2008	11.29	13.6	9.9	95.6	64.0

Site	Date	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat.)	Specific Conductivity @ 25°C (uS/cm)
25 Alton	6/19/2008	11.40	13.6	9.9	95.4	64.0
25 Alton	6/19/2008	11.53	13.6	9.9	95.1	64.0
25 Alton	6/19/2008	11.65	13.5	9.8	94.4	64.0
25 Alton	6/19/2008	11.78	13.4	9.8	94.0	64.0
25 Alton	6/19/2008	11.93	13.3	9.8	93.6	64.0
25 Alton	6/19/2008	12.11	13.2	9.8	92.9	64.0
25 Alton	6/19/2008	12.29	13.0	9.7	92.4	64.0
25 Alton	6/19/2008	12.45	12.9	9.7	91.9	64.0
25 Alton	6/19/2008	12.61	12.7	9.7	91.1	64.0
25 Alton	6/19/2008	12.76	12.5	9.6	90.1	64.0
25 Alton	6/19/2008	12.89	12.3	9.6	89.5	64.0
25 Alton	6/19/2008	13.02	12.2	9.6	88.9	64.0
25 Alton	6/19/2008	13.15	12.0	9.5	88.4	64.0
25 Alton	6/19/2008	13.28	11.9	9.5	88.1	64.0
25 Alton	6/19/2008	13.43	11.9	9.5	87.8	64.0
Pavillion	6/19/2008	0.12	19.0	9.4	101.5	70.0
Pavillion	6/19/2008	0.18	19.0	9.5	102.1	70.0
Pavillion	6/19/2008	0.28	19.1	9.4	101.8	70.0
Pavillion	6/19/2008	0.41	18.9	9.4	101.1	68.0
Pavillion	6/19/2008	0.58	18.6	9.5	101.4	68.0
Pavillion	6/19/2008	0.74	18.4	9.6	101.7	68.0
Pavillion	6/19/2008	0.91	18.4	9.6	102.1	67.0
Pavillion	6/19/2008	1.12	18.3	9.6	102.2	67.0
Pavillion	6/19/2008	1.31	18.3	9.6	102.3	67.0
Pavillion	6/19/2008	1.47	18.2	9.7	102.7	67.0
Pavillion	6/19/2008	1.64	18.1	9.7	102.9	65.0
Pavillion	6/19/2008	1.80	18.1	9.8	103.3	65.0
Pavillion	6/19/2008	1.97	18.0	9.8	103.6	65.0
Pavillion	6/19/2008	2.12	17.9	9.9	103.9	65.0
Pavillion	6/19/2008	2.28	17.9	9.9	104.0	65.0
Pavillion	6/19/2008	2.46	17.9	9.9	104.2	65.0
Pavillion	6/19/2008	2.61	17.8	9.9	104.2	65.0
Pavillion	6/19/2008	2.79	17.8	9.9	104.1	65.0
Pavillion	6/19/2008	2.94	17.8	9.9	104.2	65.0
Pavillion	6/19/2008	3.09	17.8	9.9	104.1	65.0
Pavillion	6/19/2008	3.24	17.8	9.9	104.2	64.0
Pavillion	6/19/2008	3.40	17.8	9.9	104.4	64.0
Pavillion	6/19/2008	3.54	17.8	10.0	104.6	64.0
Pavillion	6/19/2008	3.72	17.7	10.0	104.6	64.0
Pavillion	6/19/2008	3.96	17.7	10.0	104.5	64.0
Pavillion	6/19/2008	4.23	17.7	10.0	104.5	64.0
Pavillion	6/19/2008	4.52	17.6	10.0	104.5	64.0
Pavillion	6/19/2008	4.76	17.6	10.0	104.2	65.0
Pavillion	6/19/2008	4.94	17.5	9.9	103.8	65.0
Pavillion	6/19/2008	5.16	17.5	9.9	103.5	65.0

Site	Date	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat.)	Specific Conductivity @ 25°C (µS/cm)
Pavillion	6/19/2008	5.34	17.5	9.9	103.1	65.0
Pavillion	6/19/2008	5.50	17.4	9.8	102.4	65.0
Pavillion	6/19/2008	5.65	17.4	9.8	101.9	65.0
Pavillion	6/19/2008	5.78	17.3	9.8	101.6	65.0
Pavillion	6/19/2008	5.91	17.2	9.8	101.7	65.0
Pavillion	6/19/2008	6.01	17.2	9.8	101.6	65.0
Pavillion	6/19/2008	6.13	17.2	9.8	101.6	65.0
Pavillion	6/19/2008	6.34	17.1	9.8	101.2	66.0
Pavillion	6/19/2008	6.53	17.1	9.7	100.5	66.0
Pavillion	6/19/2008	6.68	17.0	9.7	100.0	66.0
Pavillion	6/19/2008	6.83	16.9	9.7	99.7	66.0
Pavillion	6/19/2008	7.02	16.8	9.7	99.4	66.0
Pavillion	6/19/2008	7.19	16.7	9.7	99.1	66.0

APPENDIX B

DETERMINING WATER QUALITY CHANGES AND TRENDS

Box and Whisker Plots

Quick Overview:

The 2008 summary New Hampshire Lakes Lay Monitoring Program (NH LLMP) reports include *box-and-whisker* plots that provide a visual representation of how the data are spread out and how much variation exists. Thus, the *box-and-whisker* plots provide a summary of how your data are distributed and provide a visual summary of how the data have varied among years and, when multiple sampling locations are monitored, provide a summary of how the data vary among sampling sites.

Basically, these plots show how the data group together for a given year. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. An algae bloom event may cause this type of outlier to occur in the chlorophyll data (high point) or Secchi disk clarity (low point).

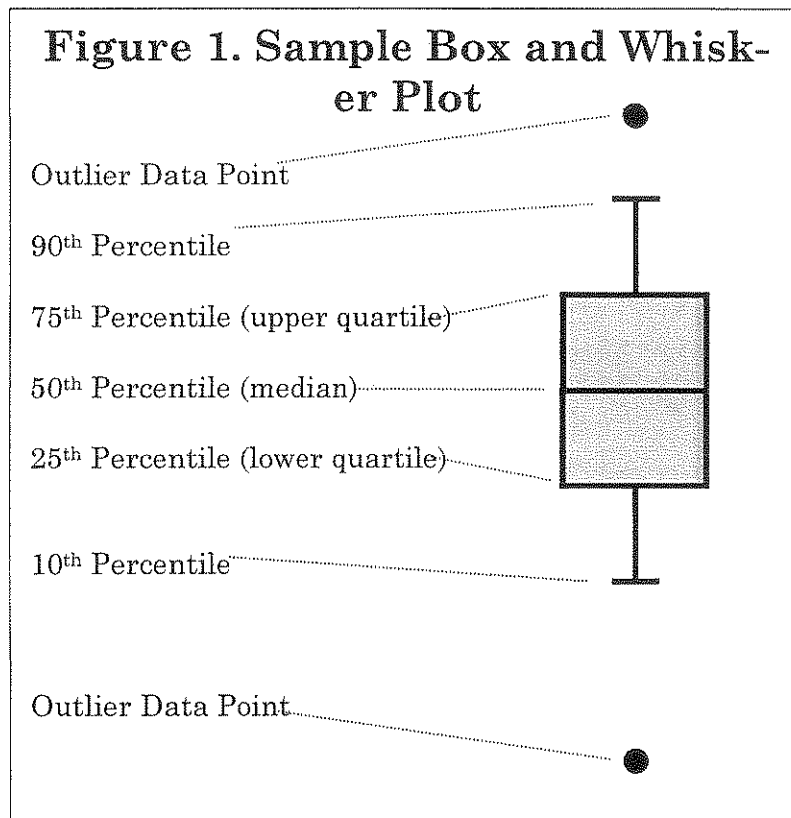
We recommend that each NH LLMP participating group plan on collecting weekly or biweekly measurements throughout the sampling season to ensure that enough data are available for this type of statistical analysis. We suggest that at least 8 data collections per year occur and generally set 10 measurements per year as a sampling effort goal per site.

We can employ the appropriate statistical techniques for detecting the extent that change is occurring when the sampling effort recommendations are followed. Your report summary should include box and whisker plots as well as a basic interpretation for your lake. If you have additional questions on interpreting your results feel free to call the Educational Program Coordinator (Bob Craycraft) at 603-862-3696.

The Details:

In the sections below we further describe the use of the box and whisker plot for those that are interested on how they are determined and how they are interpreted:

The **box-and-whisker** plot is good at showing the **extreme values** and the range of middle values of your data (Figure 1). The box depicts the middle values of a variable, while the **whiskers** stretch to demonstrate the values between which 80% of the data points will fall. The filled circles then reflect the “outlier” data points that fall outside of the whiskers and reflect values that are atypically high or atypically low relative to the other data measured for a given year.



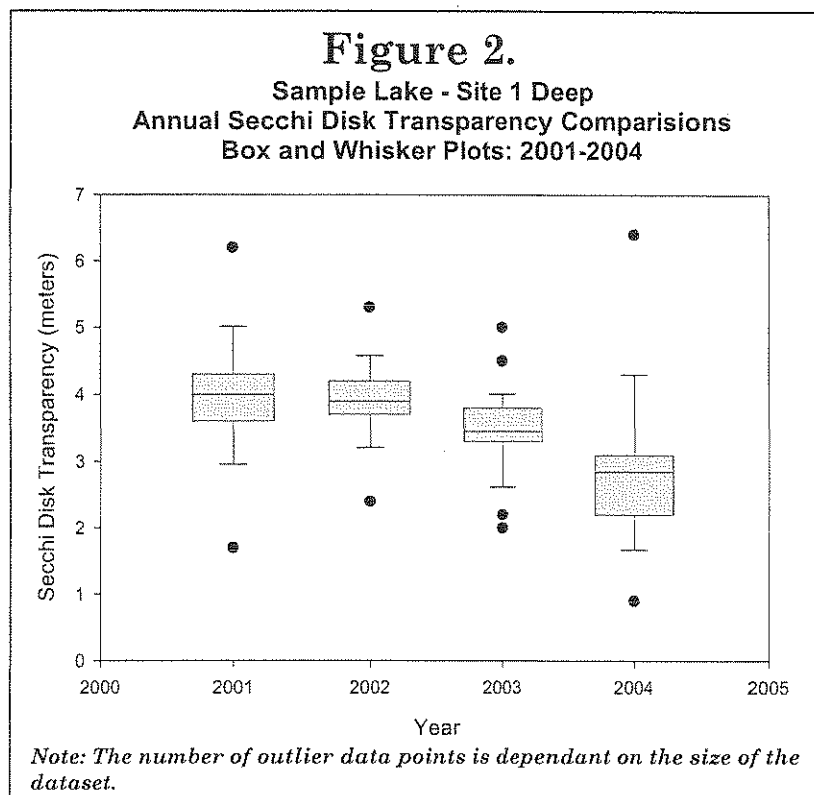
The box-and-whisker plots can be summarized as a graphic that displays the following important features of the data when they are arranged in order from least to greatest:

- Median (50th percentile) – the middle of the data
- Lower Quartile (25th percentile) – the point below which 25% of the data points are located.
- Upper Quartile (75th percentile) – the point below which 75% of the data points are located.
- 90th Percentile – the point below which 90% of the data points are located.
- 10th Percentile – the point below which 10% of the data points are located.
- Outlier Data points – data points that represent the upper 10% or the lowest 10% of the data collected for a specific year.

Note: A minimum number of data points is required to compute each feature documented above. At least three points are required to compute the Lower and the Upper Quartiles, five points are needed to compute the 10th percentile, and six points are needed to compute the 90th percentile. In the event that insufficient data points have been collected features will not be graphed due to the inability to reliably calculate the respective attribute.

Sample box-and-whisker plot interpretation:

A sample *box-and-whisker* plot is depicted in Figure 2 and it provides an opportunity to assess the usefulness of this type of plot at interpreting water quality monitoring data. The imaginary data depicted in Figure 2 reflect the annual water transparency measurements between the years 2001 and 2004. As you can glean from Figure 2, the distribution of the water clarity measurements have shifted to less clear conditions between 2001 and 2004. The median values, as well as the upper and lower quartiles (what is represented by the gray shaded box) have gradually shifted to less clear conditions over the four year span. The data points that lie between the upper and lower quartiles reflect 50% of the data collected for a given year and can provide insight into whether or not the water quality data are varying significantly between or among years. In extreme cases, when the gray shaded regions do not overlap between successive years or among years, one can quickly determine that the data distribution is significantly different for those years where the middle data (gray shading) does not overlap. Such differences can reflect long-term trends or can be a reflection of extreme climatic conditions for a given year such as atypically wet or atypically dry conditions that can have a profound impact on water quality.



Additional evaluation of the data can include a review of the 10th and the 90th percentiles (the whiskers) that provide additional insight into the distribution of the data. In this case, the trends exhibited by the 10th and the 90th percentiles are following the pattern of decreasing Secchi Disk Transparency as is exhibited by boxes (gray shaded regions). Outlier data points that fall outside of the “whiskers” can also be insightful. Such extreme values can be an early indicator of coming trends or can be an early warning sign of potential water quality problems. For instance, when Secchi Disk transparency measurements occasionally become significantly reduced (i.e. shallower

water) such phenomenon can be an indication of short-term water quality problems such as excessive sediment or an algal bloom. If such problems are not contended with, but are instead left unattended, the longer-term impact could result in an increase in the magnitude and frequency of the water transparency reductions that, in turn, would result in a decreasing trend as evidenced by a shift of the "Boxes" to shallower water transparencies. There might also be occasions when the Secchi Disk transparency outliers reflect atypically clear water clarity. Such outliers can be a sign that conditions are improving or, as is often the case, the water quality is responding to short-term climatic variations that can have a profound impact on the water quality data. For instance, the outlier data point of 6.4 meters that was documented in 2004 (Figure 2) is counter intuitive to the long term trend of decreasing water quality. Plausible explanations for such an anomaly could be due to short term overgrazing of algae by zooplankton (typical for moderate to highly productive lakes), an abrupt shift in climate that might have favored clearer water (cloudy days or cooler water) or perhaps there was some sort of human intervention, such as a fish stocking or lake treatment that would have resulted in clearer water claries.

Your 2008 executive summary in this report includes a basic interpretation of the box-and whisker plots that are specific to your lake. However, since you have personal knowledge of the conditions of your lake and local events that might influence the water quality measurements, you might have additional insight into the cause of the water quality fluctuations that have not been discussed in the report. Should you want to discuss the water quality results further, or provide additional information that you feel is important, please contact Bob Craycraft by phone, (603) 862-3696, or by email, bob.craycraft@unh.edu. Since the *box-and-whisker* plots are a relatively new addition to the annual water quality reports we would appreciate your feedback regarding whether you feel the *box-and-whisker* plots are appropriate for our volunteer monitoring audience.

APPENDIX C

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll α concentration may be low or high.

Epilimnion- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll α , and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO₂- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

Lake- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology- The shape and size of a lake and its basin.

Littoral- The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll α , Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll α values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll α and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion- Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.